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BULLETIN
of the
American Association *of* Petroleum Geologists

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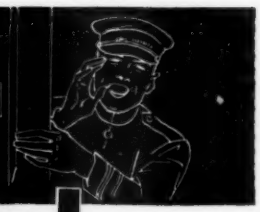

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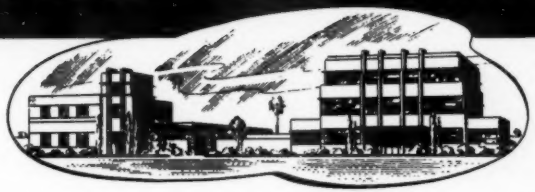

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Volume 22 Number 3

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

MARCH, 1938

ORISKANY AS A SOURCE OF GAS AND OIL IN PENNSYLVANIA AND ADJACENT AREAS[1]

CHARLES R. FETTKE[2]
Pittsburgh, Pennsylvania

ABSTRACT

The discoveries of relatively large volumes of gas in the Oriskany sandstone in the Wayne-Dundee field in Schuyler County, New York, in March, 1930, and in the Tioga field in Tioga County, Pennsylvania, in September, 1930, first focused attention on this Lower Devonian formation as a potential source of gas in the northern Appalachian Plateau province. The areal distribution, thickness, and physical characteristics of the Oriskany sandstone are described. Most of the Oriskany gas production in the northern part of the province has come from eight pools located in south-central New York and north-central Pennsylvania. Their location, size, structure, and other pertinent features are described. Oil in commercial quantities in the Oriskany has been encountered in only two small pools in eastern Ohio. Analyses of connate waters from the Oriskany sandstone from several widely separated areas are given. A relationship between the composition of the hydrocarbon gases found in the Oriskany and the degree of metamorphism of the associated strata is pointed out. Possible reserves in the Oriskany in Pennsylvania are discussed.

Early in the present century a small gas pool was opened in the vicinity of Austinburg in northeastern Ohio in a sandstone at the Oriskany horizon. About 1923 gas in commercial quantities was encountered in Oriskany sandstone west of Cambridge in Guernsey County, Ohio, and a few years later oil was discovered in the same formation along the eastern edge of the gas-producing area. However, it was the discoveries of relatively large volumes of gas in the Oriskany sandstone in the Wayne-Dundee field in Schuyler County, New York, in March, 1930, and in the Tioga field in Tioga County, Pennsylvania, in September, 1930, that focused attention on this formation as a potential source of gas in the northern Appalachian province.

[1] Read before the mid-year meeting at Pittsburgh, October 15, 1937. Published by permission of the State geologist of Pennsylvania.

[2] Professor of geology, Carnegie Institute of Technology.

Stratigraphy

The Oriskany sandstone is of Lower Devonian age. It receives its name from Oriskany Falls, Oneida County, in east-central New York, where it consists of a nearly pure quartz sandstone 20 feet in thickness. In the folded Appalachians, the term Oriskany has come to be applied to a group which is made up of two distinct formations shown to be closely related by a similarity in faunal content.[3] The upper sandstone beds of the group are called the Ridgeley formation, and the lower siliceous limestones, shales, and cherts, the Shriver formation. The term "Oriskany" as commonly used in the gas fields of north-central and western Pennsylvania is restricted to the Ridgeley part of the group.

Along the Allegheny front and in most of central Pennsylvania, the Oriskany group rests disconformably on the New Scotland formation of the Helderberg group, the Becraft limestone, the uppermost member of the latter group being absent. Westward, the Shriver and the entire Helderberg group are gradually cut out. In western New York, the Oriskany sandstone, where present, rests on a dolomitic limestone of Upper Silurian age.

In central Pennsylvania, the Oriskany sandstone is succeeded by limy shales and limestones of Onondaga age. The contact is everywhere sharp. In places the top of the sandstone contains limonite and in other places hematite. This fact, added to the great variation in thickness (in some places total absence) and the complete faunal break, points to the existence of an unconformity between the Oriskany and the Onondaga.[4]

The strata overlying the Oriskany in western Pennsylvania have been classified as follows.

Permian system
  Dunkard series
Pennsylvanian system
  Monongahela series
  Conemaugh series
  Allegheny series
  Pottsville series
Mississippian system
  Mauch Chunk red shales
  Pocono sandstones and shales (Berea sandstone and Knapp beds at base)
Devonian system
  Upper
    Conewango group { Oswayo gray shales and sandstones / Cattaraugus red beds—uppermost Catskill }
    Chemung group of shales and sandstones

[3] Arthur B. Cleaves, "Oriskany Thicknesses in Pennsylvania," *Proc. Pennsylvania Acad. Sci.*, Vol. 11 (1937), pp. 64–71.

[4] *Ibid.*

Portage group of shales and sandstones (Burket (Genesee) black shale in lower part, with Tully limestone at base)
Middle
Hamilton group of shales (*Marcellus* black shale at base)
Onondaga limestone

In Tioga County, Pennsylvania, the Onondaga limestone is relatively thin, 10–20 feet. Chert is absent. Eastward a series of dark gray, calcareous shales, and intercalated thin limestone beds appear between this limestone and the Oriskany sandstone that are probably also of Onondaga age. These attain a thickness of nearly 200 feet in the vicinity of Towanda in Bradford County. West of Tioga County, the Onondaga limestone thickens and becomes decidedly cherty.

Throughout north-central Pennsylvania, the Tully limestone, at the base of the Upper Devonian, is the only good horizon marker between the base of the Catskill red beds and the top of the Onondaga limestone that can be traced over any great distance in the subsurface sections. The Tully has its greatest development on the outcrop in the vicinity of Lock Haven and Jersey Shore in Clinton and Lycoming counties, where it consists of more than 200 feet of limestone.[5] In subsurface sections, thicknesses of 130–140 feet have been encountered in Bradford and Clearfield counties. It can be recognized as far west as Elk and McKean counties. Here it has thinned to less than 5 feet. Farther west, what is probably a lower limestone, stratigraphi-

TABLE I

WEST-EAST SECTIONS ACROSS WESTERN PENNSYLVANIA

	Section 1 Jas. H. Duff et al. J. Scott Munnell No. 1, Slippery Rock Twp., Lawrence Co., Pa.	*Section 2 F. C. Deemer's W. H. Irwin Tract No. 1, Gaskill Twp., Jefferson Co., Pa.*	*Section 3 Susquehanna Oil and Gas Co.'s Jno. Woolridge Est. No. 1, Bradford Twp., Clearfield Co., Pa.*	*Section 4 Outcrop Section Bellefont Quad. Centre Co., Pa. U.S.G.S. Bull. 855, Pl. 3*
	Feet	*Feet*	*Feet*	*Feet*
Pennsylvanian system	228+	306+	276+	10+
Mississippian system	483	894	834	1,130
Devonian system				
Upper				
Catskill	390	492	1,308	1,600
Chemung and Portage	3,152	5,002	4,627	4,650
Middle				
Hamilton	248	481	620 est.*	700
Onondaga	134	62		Absent

* Woolridge well No. 1 was drilled to a total depth of 7,490 feet. The Tully limestone occupied the interval between 6,903 and 7,045 feet. It is estimated that the top of the Oriskany would have been reached at a depth of 7,665 feet.

[5] Bradford Willard, "Tully Limestone and Fauna in Pennsylvania," *Bull. Geol. Soc. America*, Vol. 48 (1937), p. 1241.

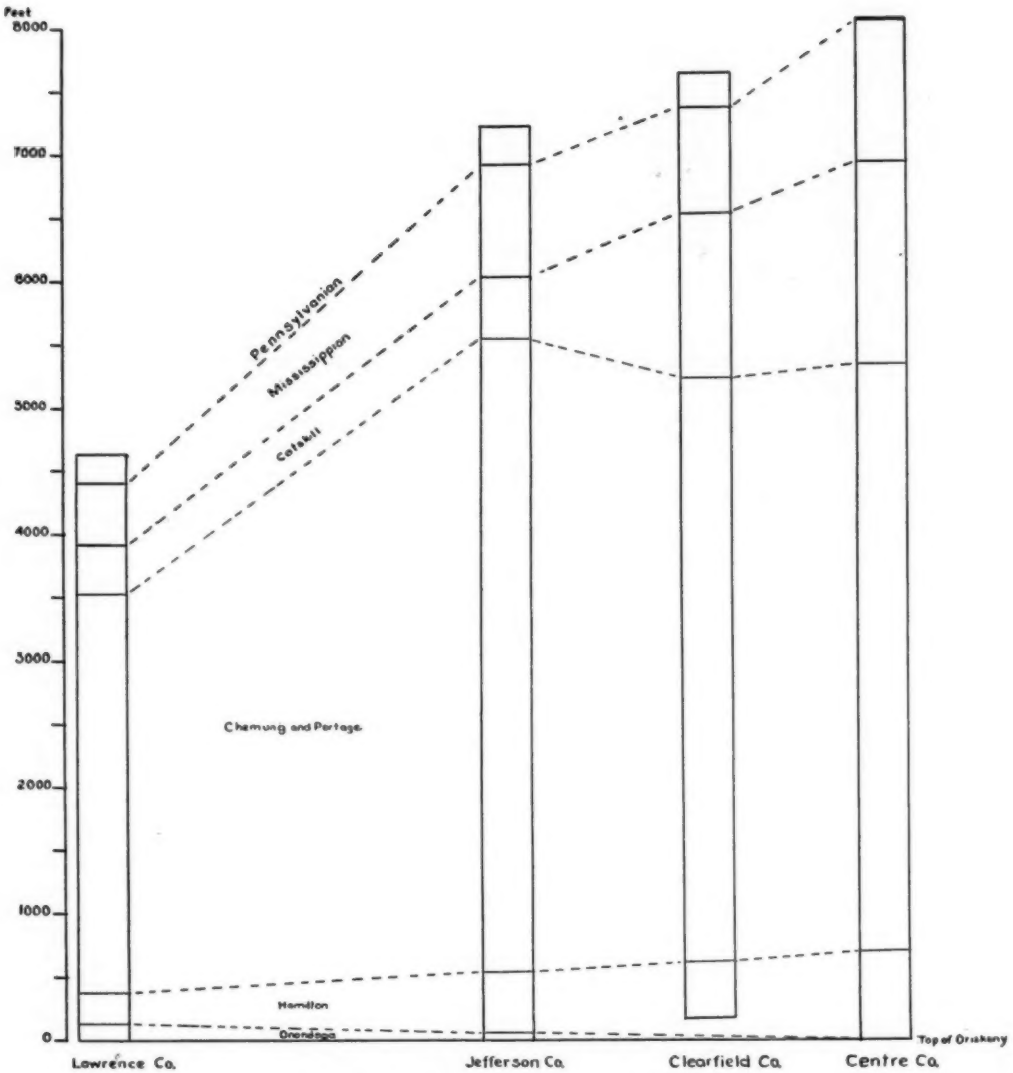


FIG. 1.—West-east sections across western Pennsylvania.

cally, makes its appearance in the upper part of the Hamilton shales in the well sections. Whether or not this limestone represents a single horizon comparable with the Tully in continuity has not yet been determined.

The Appalachian structural front, only a short distance east of the Allegheny front, corresponds with the thickest zone of sedimentation in the Appalachian geosyncline from early Devonian up through and including Pottsville time.[6] In the northern Appalachian Plateau province, the formations, particularly those of the Upper Devonian, thicken as the structural front is approached. This is exemplified by the four sections given in Table I and shown graphically in Figure 1. Sections 1 and 2 are 70 miles apart; 2 and 3, 30 miles; and 3 and 4, about 25 miles.

Areal Distribution and Thickness

The Oriskany sandstone is probably present along the entire length of its outcrop southeast of the Allegheny front.[7] At Hyndman, in Bedford County, the Oriskany sandstone (Ridgeley) is hard, tough, calcareous sandstone approximately 89 feet thick. Twelve miles northeast (near Bedford Springs), an incomplete section contains 105 feet. In Blair County, 30 miles north of Bedford Springs, in the vicinity of Hollidaysburg, the thickness is approximately 110 feet. At Mount Eagle, Centre County, 48 miles northeast of Hollidaysburg, the sandstone is 50 feet thick. Twenty-seven miles northeast, on Pine Creek near Jersey Shore, Lycoming County, approximately 93 feet are exposed.

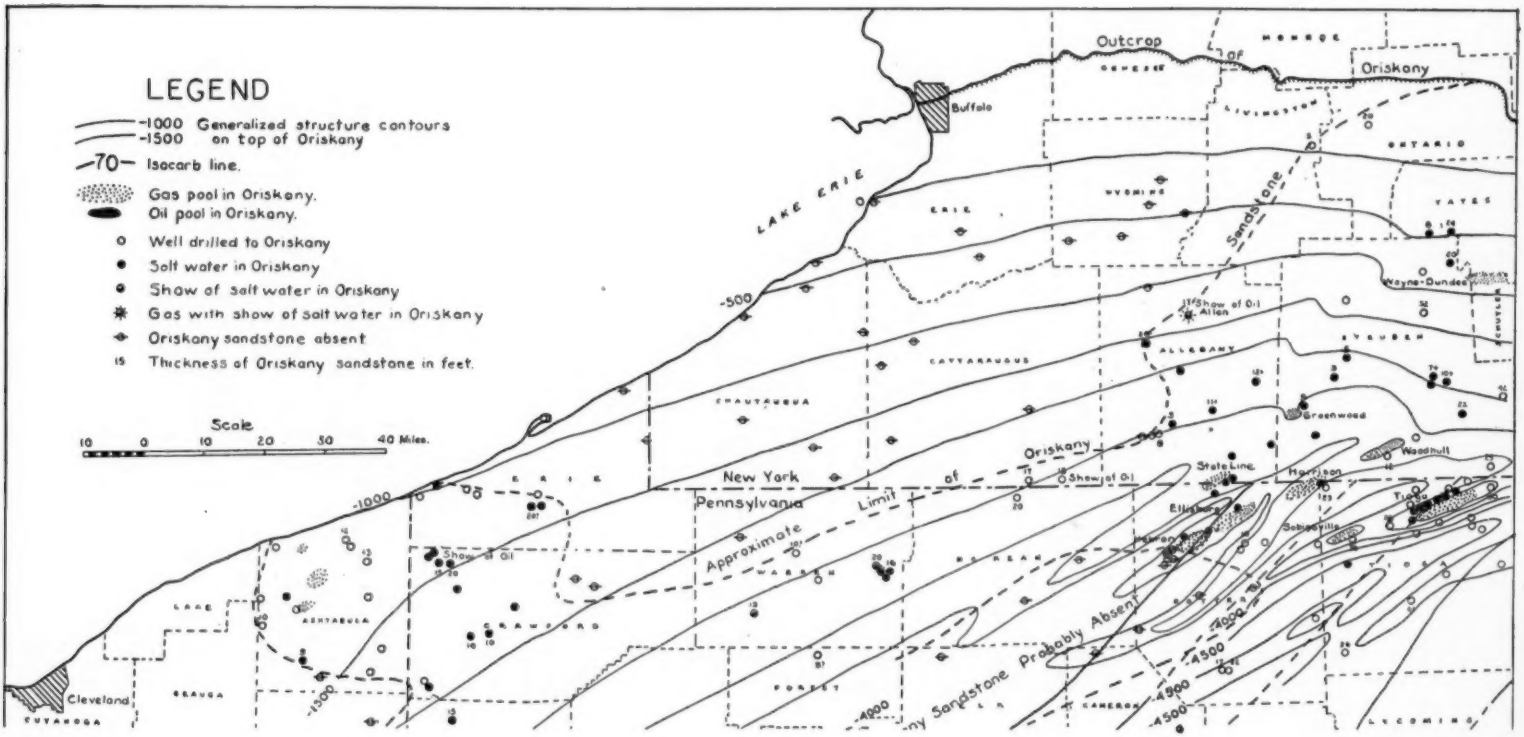
Along the outcrop of the Oriskany horizon in western New York, the sandstone attains a moderate development only near Phelps, Ontario County, where the thickness is slightly more than 6 feet.[8] Exposures in Monroe County show sandstone 8–14 inches in thickness, and in Genesee County 6–8 inches in thickness. Not more than a trace occurs in Erie County.

No well developed sandstone occurs along the outcrop of the Oriskany horizon across central Ohio, although the basal layer of the Columbus limestone, the approximate equivalent of the Onondaga, is sandy in places. The small patches of sandstone that occur between the Upper Silurian dolomites and the Upper Devonian shales in the

[6] Paul H. Price, "The Appalachian Structural Front," *Jour. Geol.*, Vol. 39 (1931), pp. 40–43.

[7] Arthur B. Cleaves, *op. cit.*, pp. 64–71.

[8] D. H. Newland and C. A. Hartnagel, "Recent Natural Gas Developments in South Central New York," *New York State Mus. Circ. 7* (1932), p. 13.


LEGEND
-1000 Generalized structure contours
-1500 on top of Oriskany
-70- Isocarb line.
Gas pool in Oriskany.
Oil pool in Oriskany.
Well drilled to Oriskany
Salt water in Oriskany
Show of salt water in Oriskany
Gas with show of salt water in Oriskany
Oriskany sandstone absent
15 Thickness of Oriskany sandstone in feet.
Scale
10 0 10 20 30 40 Miles.
Outcrop of Oriskany
Buffalo
LAKE ERIE
Cleveland
-500
-1000
-1500
-4000
-4500
New York
Pennsylvania
Approximate Limit of Oriskany
Oriskany Sandstone Probably Absent
Sandstone
Show of Oil
Allen
Greenwood
Woodhull
State Line
Harrison
Ellisburg
Sabinsville
Tioga
Wayne-Dundee
ERIE
CHAUTAUQUA
CATTARAUGUS
ALLEGANY
STEUBEN
ONTARIO
YATES
LAKE
ASHTABULA
CRAWFORD
WARREN
FOREST
CAMERON
LYCOMING
CUYAHOGA
GENESEE
LIVINGSTON
WYOMING
MONROE

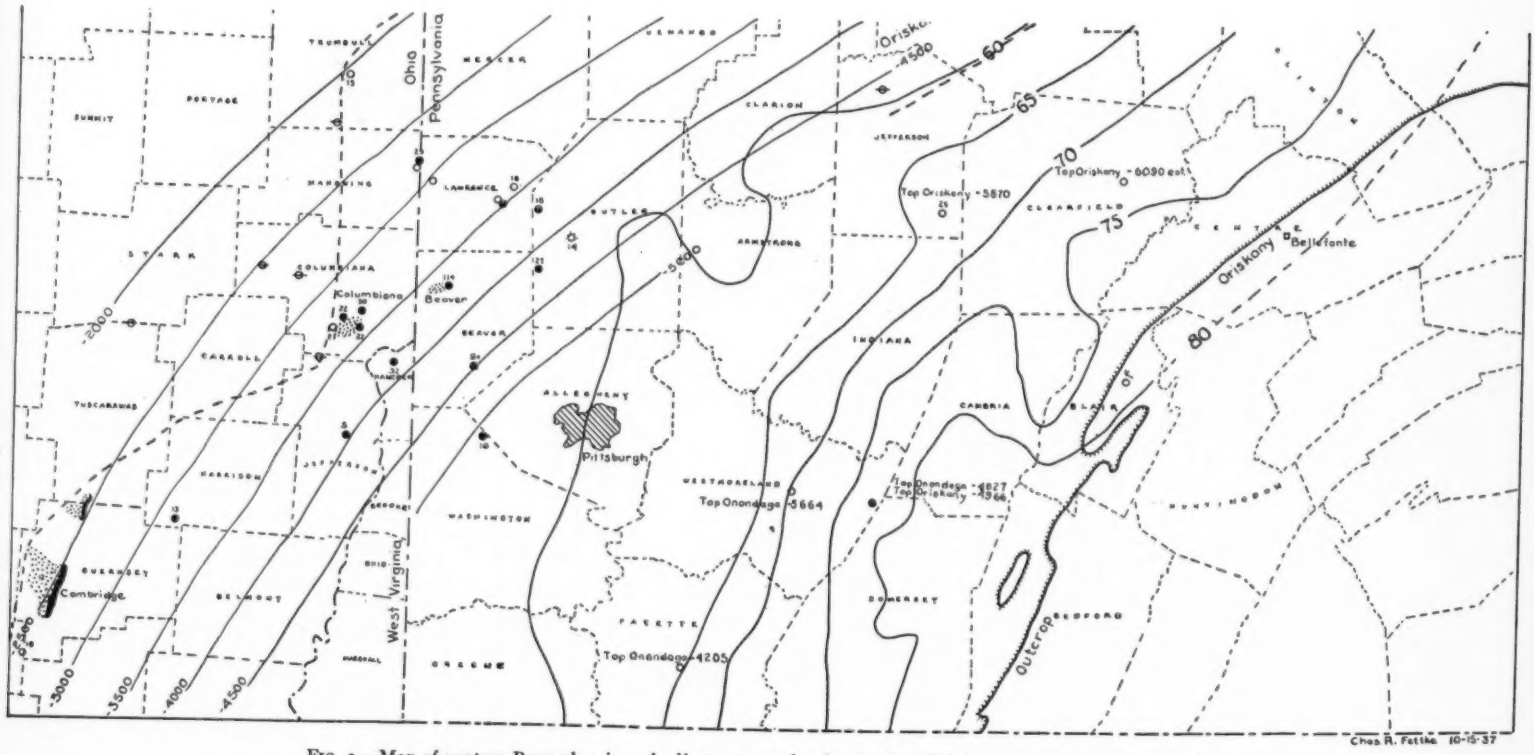


FIG. 2.—Map of western Pennsylvania and adjacent areas showing depth of Oriskany sandstone below sea-level.

vicinity of Hillsboro in Highland County, southwestern Ohio, may possibly represent the Oriskany.[9]

The approximate northwestern limit of the area, which has been shown by drilling to be underlain by a nearly continuous bed of sandstone at the Oriskany horizon, is indicated by a dashed line in Figure 2. It is quite probable, however, that small lenses of sandstone are present locally at considerable distances beyond the more continuous body of sandstone. In most of the area outlined, the sandstone is relatively thin. It exceeds 30 feet in few places, and the average thickness is probably somewhat less than 15 feet. The greatest thicknesses northwest of the Allegheny front have been encountered in Tioga County, Pennsylvania, where some wells were drilled through as much as 60 feet of sandstone at the Oriskany horizon.

Within the main area of sandstone, drilling has outlined only one large area, in most of which the Oriskany sandstone seems to be absent. This includes a considerable part of southwestern Potter, southern McKean, northwestern Cameron, northwestern Elk, southeastern Forest, and northern Jefferson counties. The southwestern extent of the area has not yet been determined.

In Fayette County, the Leo F. Heyn well, No. 1, on the Chestnut Ridge anticline, southeast of Uniontown, encountered gas in commercial quantities in cherty Onondaga limestone and was, therefore, not completed to the Oriskany. At McCance, in Westmoreland County, the Peoples Natural Gas Company's No. 1842 on the Chestnut Ridge anticline passed through the Oriskany horizon. No gas or water was present. Unfortunately, the drillers neglected to save samples of the cuttings from the Oriskany interval and no definite information is available as to the characteristics of the formation at this locality. An earlier well, about 500 feet away, encountered gas in the cherty Onondaga limestone. When an attempt was made several years later to deepen this well, a large flow of salt water was encountered in the limestone a short distance below the gas, and the well was abandoned. The Snee and Potter Development Company's Indiana Savings and Trust well No. 1 on the Laurel Ridge anticline in eastern Westmoreland County entered the Oriskany sandstone, 139 feet below the top of the Onondaga limestone. Some gas and a little salt water had previously been encountered in the limestone, all but the upper 20 feet of which was very cherty. About 3.5 feet in the sand, a large flow of salt water entered the well. Drilling was discontinued after 7 feet of sandstone had been penetrated.

[9] J. Ernest Carman and Ernest O. Schillhahn, "The Hillsboro Sandstone of Ohio," *Jour. Geol.*, Vol. 38 (1930), p. 259.

The Oriskany sandstone is exceptionally pure quartz sandstone. At the beginning of Devonian time the land mass of Appalachia (along the eastern margins of the North American continent) stood only a short distance above sea-level and supplied little in the way of clastic sediments to the adjacent Appalachian trough, which was occupied by a narrow arm of the sea in which the limestones and calcareous shales of the Helderberg group accumulated.

Over the low land mass on the east, chemical decomposition of the exposed rocks was an important factor in the weathering process in contrast to mere mechanical disintegration. All of the silicate minerals accompanying the quartz in the rocks were thoroughly altered and disintegrated into soft, readily pulverized secondary products, leaving the quartz grains free. As there is no evidence that an extensive protective cover of vegetation existed in early Devonian time it is probable that winds separated and blew away much of the fine material. As a result, a sandy mantle accumulated over the low lands of Appalachia.

During the latter part of Oriskany time, a slight uplift of the land mass caused streams to shift this sand to the adjacent shallow Oriskany sea. As the sea advanced westward the sand was gradually spread over a wider and wider area, waves and shore currents aiding in the process. After its deposition the sea for a time withdrew from the region, exposing the sand to erosion before the Onondaga limestone was laid down over it.

Structure

Structurally, the Appalachian Plateau province is a broad asymmetrical synclinorium whose long axis trends northeast and southwest, with the steep limb on the southeast side. The central part of the plateau, in southeast Ohio, southwest Pennsylvania, and northwest West Virginia, is floored with beds of Permian age which are surrounded by outcrops of Pennsylvanian beds. Mississippian, Devonian, Silurian, and older strata crop out in sequence along the western, northern, and eastern margins.

On the southeast, the plateau terminates along the Allegheny front and adjoins the closely folded Appalachians. The southeastern limb of the synclinorium in its northern part is modified by a series of somewhat prominent anticlinal and synclinal foreland folds with axes trending approximately parallel with the long axis of the synclinorium. Some of the anticlines in places rise to heights of 2,500 feet or more above adjoining synclines, but folds 300–800 feet high are more numerous. The folds become less prominent in the central part of the

synclinorium and are hardly perceptible on the northwestern limb.

The foreland folds have trends approximately parallel with those of the closely folded Appalachians on the southeast. They die out gradually northwestward from the Allegheny front. The same forces which produced the folded and faulted structures of the Appalachian mountains, no doubt also caused the development of the foreland folds and the two zones of structural features, therefore, have a similar age and origin. The foreland folds represent diminishing activities of tangential compressive forces which originated on the southeast.

In western New York and northwestern Pennsylvania, the regional dip of the surface formations is toward the south. Due to the fact that most of the underlying formations thicken in a southeasterly direction, the regional dip of the deeper strata swings toward the southeast. This is exemplified by the generalized structure contours drawn on the top of the Oriskany sandstone in Figure 2. Similar contours drawn on the top of the Medina sandstone would show a still greater shift toward the east.

Sherrill has shown that the typical northern Appalachian foreland folds are basically asymmetrical.[10] The anticlines are steeper on the flank facing the more intensely deformed mountains, in contrast to the anticlines of the mountains proper, which, with few exceptions, have their steepest dips on the side facing the foreland folds and are commonly overturned or overthrust in that direction. Sherrill suggests that the asymmetry of the foreland folds is primarily a result of the wedge-like form of the sedimentary cover, and that the reason for the asymmetry of the folds is to be found largely in a combination of (1) the obliquely upward rise of the anticlines due to the initial dip of the basement surface toward the present structural front, (2) underthrusting, and (3) a tendency of the sediments to flow into the deepest part of the basin.

In north-central Pennsylvania and the immediately adjacent parts of New York, drilling has revealed the presence of extensive north-dipping, reverse faults at the Oriskany horizon along the south flanks of the anticlines in at least seven of the gas pools developed to date. Many of the faults have displacements of several hundred feet. The faults have strikes approximately parallel with the axes of the folds.

Physical Characteristics of Oriskany Sand

In the productive areas of south-central New York and north-central Pennsylvania, the gas has been encountered in the upper part

[10] R. E. Sherrill, "Symmetry of Northern Appalachian Foreland Folds," *Jour. Geol.*, Vol. 42 (1934), p. 247.

of the Oriskany sandstone. This consists of a fairly tightly cemented, comparatively pure, medium-grained quartz sandstone ranging in color from light gray to light brownish gray. Thin sections prepared from fragments blown from the productive portions in the Tioga and Hebron pools were found to consist almost entirely of an interlocking mosaic of quartz grains possessing average diameters in the coarser parts between 0.5 and 1.5 millimeters, and in the finer parts, between 0.3 and 0.4 millimeter. In thin section, most of the grains appear to be angular or subangular, but careful examination reveals that this angularity is due, in part at least, to the secondary crystalline outgrowth of silica from grains that originally were round. Such secondary silica is the chief cementing material. Thin sections of fragments from the upper part of the sandstone blown from productive wells, as a rule, contain only a very small amount of calcite irregularly distributed among the quartz grains. This is in marked contrast to the lower part of the sandstone, which, in places where it has been penetrated by non-productive wells, is almost invariably markedly calcareous. The upper part of the sandstone in non-productive wells, though not as calcareous as the lower, is commonly somewhat calcareous. Inasmuch as the productive wells stop in the upper part where the gas is encountered, it is not known whether the lower part in these wells also is calcareous.

Screen analyses of typical fragments of Oriskany sandstone from two wells in the Tioga field, Pennsylvania, and one from the Wayne-Dundee pool in New York, are given in Table II. An analysis of a series of samples taken across the entire thickness in a quarry at Mapleton Depot, Huntingdon County, Pennsylvania, where the Oriskany sandstone has its greatest development in central Pennsylvania and is 190 feet thick, is included for comparison. A close similarity both in grain size and degree of sorting is shown by the four samples. The central Pennsylvania sample is only slightly coarser than those from the gas fields.

The average total porosity by volume of 65 fragments of Oriskany sandstone obtained from 19 different producing wells in the Tioga field, Pennsylvania, was 8.8 per cent. If the 8 samples from two of the wells whose porosities were lowest, ranging between 2.9 and 5.0 per cent, are eliminated, the average porosity of the remaining 57 is 9.5 per cent, the porosities of individual fragments ranging from a minimum of 7.1 to a maximum of 11.8 per cent. A single fragment from the Sabinsville pool possessed a porosity of 9.9 per cent; six fragments from two wells in the Hebron field had an average porosity of 9.4 per cent, ranging from 9.1 to 10.1; and four samples from a single well in

TABLE II

SCREEN ANALYSES OF FOUR SAMPLES OF ORISKANY SANDSTONE

Size of Openings Millimeters		*East Penn Development Co's. J. A. Leslie No. 1, Tioga Field, Pa.*	*Penn-United Gas Co's. Ida Russell No. 1, Tioga Field, Pa.*	*Lycoming Producing Corp't's. Crosby No. 1, Wayne-Dundee Pool, New York*	*Quarry at Mapleton Depot, Huntingdon Co., Pa.*
Through	*Caught On*				
		Per Cent	*Per Cent*	*Per Cent*	*Per Cent*
4.699	3.327				.4
3.327	2.362				.7
2.362	1.651				1.8
1.651	1.168		.2		1.6
1.168	.833	1.3	3.2	2.2	2.5
.833	.589	6.9	14.1	4.1	7.5
.589	.417	21.3	22.8	16.2	19.1
.417	.295	32.3	30.8	42.2	48.0
.295	.208	24.1	21.0	21.7	14.9
.208	.147	7.0	4.1	6.5	2.2
.147	.104	3.2	1.7	3.1	.5
.104	.074	1.8	1.0	1.8	.4
.074		2.1	1.1	2.2	.4

the Wayne portion of the Wayne-Dundee pool of New York, an average of 8.3 per cent, ranging from 7.1 to 9.0 per cent.

At the time the determinations were made it hardly seemed possible that a sandstone of as low a porosity as that of the fragments tested could possess sufficient permeability to account for the large open-flow capacities of the wells from which the fragments came. One explanation naturally was that the sandstone varied greatly in porosity vertically as well as horizontally and that the fragments blown out of the wells represented only the tightest parts. The occurrence of small but well developed quartz crystals, showing prism faces and terminated by pyramids, on the surfaces of most of the fragments from the Farr Heirs well No. 1 in the Tioga field, however, suggested another possibility. Crystals of the type described could hardly develop except by growing out from a wall into an open cavity. One of the fragments showed a plane surface studded with quartz crystals. In the other, the surfaces were slightly curved. This occurrence seemed to indicate the possibility that secondary cavities had been developed by fracturing along the anticlinal axis and the fault zones, and that these account for the high degree of permeability of the sandstone and in some cases may also constitute an appreciable part of the reservoir space for the gas.[11]

Since the foregoing observations were made, the Belmont Quadrangle Drilling Corporation has taken a core of the upper 5.7 feet

[11] Charles R. Fettke, "Physical Characteristics of the Oriskany Sandstone and Subsurface Studies in the Tioga Gas Field, Pennsylvania," *Pennsylvania Top. and Geol. Survey Bull. 102B* (1931), p. 2.

of Oriskany sandstone in its Van Campen well No. 2 in the State Line field of Allegany County, New York. The core has a diameter of 4 centimeters. It consists of brownish gray quartz sandstone firmly cemented by secondary silica. The most interesting feature exhibited is the occurrence of two parallel fractures a little less than 1 centimeter apart that extend almost the entire length of the core. Along these fractures at short intervals are connected sheet-like vugs lined with minute quartz crystals and a few calcite rhombs. The walls of the openings are 1–1½ millimeters apart.

Arthur C. Simmons has determined the porosities and the permeabilities, both parallel with, and perpendicular to, the bedding, of 18 samples taken at approximately equal intervals along the length of the core. He found the average porosity to be 10.3 per cent, the minimum being 7.9 per cent and the maximum 12.2 per cent. The samples tested were selected from parts of the core free from fractures. It is interesting to note that the porosities of the fragments blown from the wells are representative of the pay portion of the sand as a whole. The average permeability of the 18 samples parallel with the bedding was found to be 270.9 millidarcys, and perpendicular to it, 163.4 millidarcys.

Description of Oriskany Sand Pools

North-central Pennsylvania and south-central New York

The major Oriskany gas developments in the northern Appalachian Plateau province have been confined to south-central New York and north-central Pennsylvania. Northwest of the structural front in north-central Pennsylvania, the Sabinsville anticline, the fourth of the prominent foreland folds in that direction, distant about 40 miles from the front, is the first one along which commercial production has been obtained. The Sabinsville and Tioga fields are located along this anticline, about 10 miles apart.

Tioga field

The Tioga field, in northern Tioga County, Pennsylvania, is on a prominent elongate dome along the axis of the Sabinsville anticline. Opposite the highest part of the dome the Oriskany sandstone descends 1,450 feet on the north in a distance of 4.5 miles, or at a rate of about 320 feet per mile, to the axis of the Cowanesque syncline, and 2,650 feet on the south in a distance of 3.5 miles, or at a rate of about 760 feet per mile, to the axis of the Pine Creek syncline. The

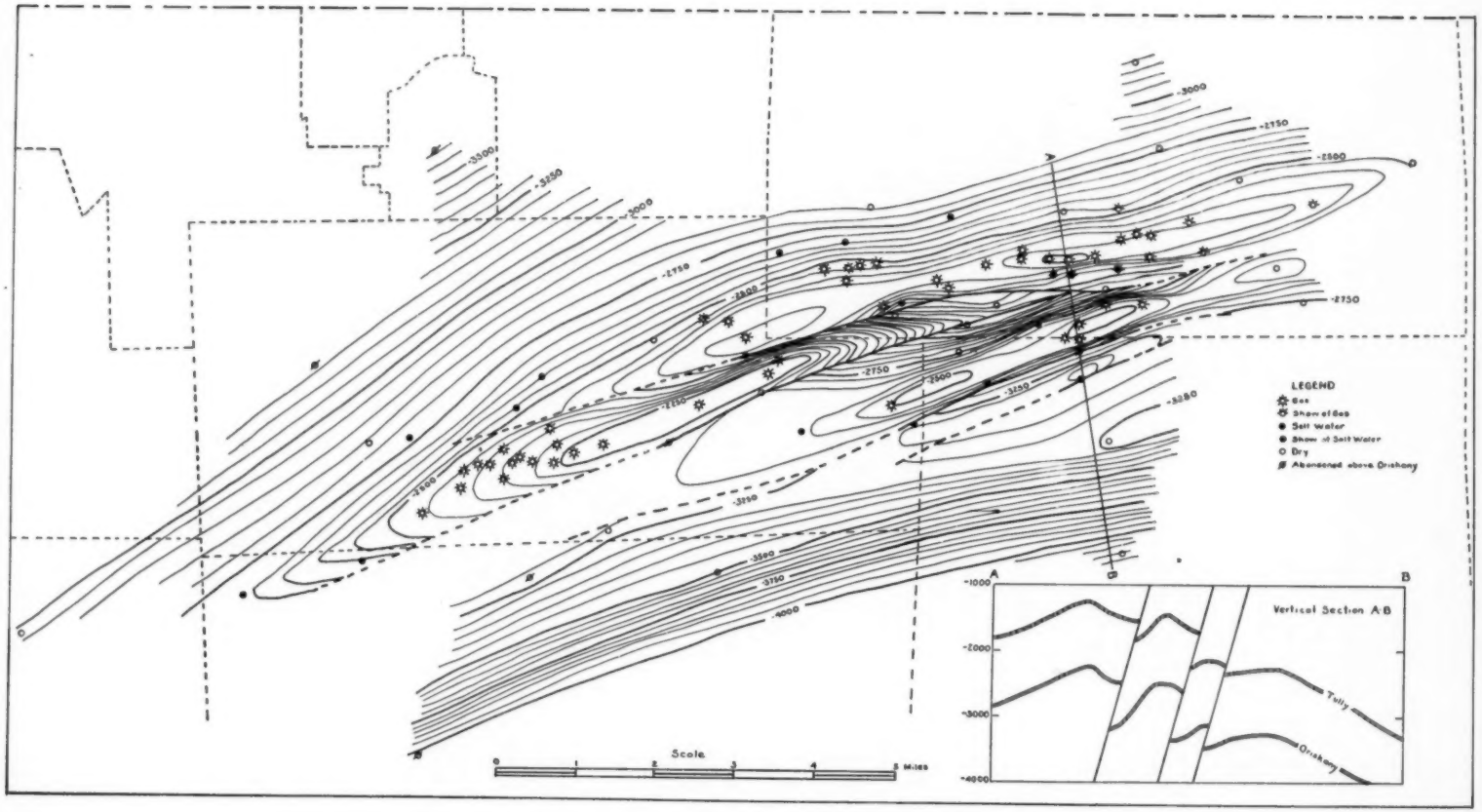


FIG. 3.—Structure map of Tioga gas field, Pennsylvania.

dome is modified by a series of reverse faults that trend approximately parallel with the axis of the fold.[12] One of the faults has a throw of at least 700 feet (Fig. 3).

The relatively complex structure of the Tioga dome probably is due in part to an upward flow of the relatively incompetent Salina beds beneath the more competent but much thinner and more brittle Tonolaway, Helderberg, and Oriskany beds beneath the dome, which commenced as soon as the tangentially directed compressive stresses of the Appalachian revolution transmitted through the basement rocks caused the arch to begin to rise. In the L. E. Shoemaker well No. 1 near the northeast edge of the field, the abnormal thickness of 2,887 feet of Salina beds, of which 954 feet consisted of salt, had been penetrated at the time the well was abandoned. Large fragments of the light greenish gray Salina shale, brought to the surface in the bailer, were much brecciated, with interlacing calcite veinlets filling the fractures.

The Tioga field extends about 11 miles along the axis of the Sabinsville anticline. Faults separate the field into at least two and probably three distinct pools. The Elbridge or western pool had a productive closure of about 300 feet; the Boom or eastern, about 230 feet; and the Meaker or southern, 70 feet. The total productive area includes approximately 7,100 acres. Original reservoir pressure was approximately 1,650 pounds per square inch, or about equal to the hydrostatic head, the average depth of the wells being 4,000 feet. Some of the wells had initial open-flow capacities of as high as 73 million cubic feet per day and many exceeded 10 million.

Salt water was encountered in some but not all wells in a narrow belt along the north flank of the Elbridge and Boom areas and also on the north flank of the Meaker structure. On the south flank salt water was confined to wells on, or close to, fault zones. Down the pitch at the southwest end salt water is present in the sand. At the northeast end the sand is dry. Outside the relatively narrow belt, partly encircling the gas-bearing area, no salt water was encountered on either the north or the south flank. The sandstone apparently has such low porosity and permeability that it is not capable of yielding any fluids. Unfortunately, no cores have been taken in the dry areas to prove this.

It seems reasonable that originally the porosities and permea-

[12] J. French Robinson, Verner Jones, and J. Gaddess, "Sub-Surface Structural Geology of the Northern Appalachian and Southern New York Gas Fields," *Pennsylvania State College Min. Indus. Exper. Sta. Bull. 11* (1932), Map 3.

S. H. Cathcart and T. H. Myers, "Gas in Tioga County, Pennsylvania," *Pennsylvania Top. and Geol. Survey Bull. 107* (1934), Fig. 4.

bilities of the sand were nearly uniform throughout the region and that the pores of the sand were filled with salt water. Gas, generated from organic matter in the adjacent sediments, accompanied no doubt by water, entered and migrated through the sand as compacting and later dynamic forces consolidated and metamorphosed the strata. Much of the gas was trapped underneath the structural "highs." In these parts it largely replaced the water in the sandstone. During the period of dynamic metamorphism the sandstone in the Tioga region in general underwent sufficient cementation and recrystallization greatly to reduce its porosity. Cementation and recrystallization, however, proceeded further in those parts of the sand saturated with water than in those parts that were relatively dry.

The close relationship between the initial reservoir pressure and the present hydrostatic head suggests that there has been a slow seepage of gas out of the reservoir along joints, fractures, and other minute openings as removal of overlying strata by erosion proceeded. Water has followed the gas up the structure and the process of cementation has probably continued in the water-saturated parts of the sandstone, leaving only a relatively narrow band of salt water around part of the field.

The Tioga field is practically exhausted. There has been relatively little water encroachment. Only edge wells along the north flank and in the narrow Meaker pool were flooded out. About 36 billion cubic feet of gas, or approximately 5 million cubic feet per acre, have been recovered. In the development of the field, 92 wells were drilled. Of these 47 were producers, 17 encountered salt water, 22 were dry, and 6 were abandoned before they reached the sand because it was found that they were located along fault zones or were too far down the flanks of the structure. Four of the completed wells were also located far down the flanks of the structure.

SABINSVILLE POOL

The Sabinsville pool, in northwestern Tioga County, Pennsylvania, about 10 miles slightly south of west of the Tioga field, is on another elongate dome along the axis of the Sabinsville anticline. A north-dipping reverse fault, probably trending nearly parallel with the fold, with a throw of approximately 600 feet, bounds the dome on the south side.

The initial rock pressure was 2,125 pounds per square inch, or somewhat above hydrostatic head, as the average depth of the top of the sand is 4,350 feet.

The field was opened in August, 1935. There are 14 producing

wells, which had initial open-flow capacities varying from 3 to 50 million cubic feet of gas per day, in an area about 3 miles long and 0.5 mile wide at its widest part. Only one dry hole, which intersected the fault, had been drilled to September, 1937. One well had not been completed. An effective closure of 250 feet has been demonstrated. There is no information as yet in regard to the occurrence of salt water around the margins of the pool.

During September a well was completed about one mile north of the northeast end of the developed area on the northwest flank which encountered an open flow of about 1.5 million cubic feet of gas per day with the top of the sand 350 feet lower than in the lowest producing well in the developed area. This well showed a reservoir pressure of only 1,105 pounds, which was approximately the same as that to which the developed area had been reduced by withdrawals at the time, indicating that some connection with the main area must exist that has enabled the pressure to become equalized.

HARRISON ANTICLINE

Two pools have been developed along the Harrison anticline, the next anticline northwest of the Sabinsville anticline. One, the Harrison pool, is in northeastern Potter County, Pennsylvania, and the other, the Woodhull pool, in southern Steuben County, New York. The developed part of the Harrison pool has a length of 7 miles along the axis and a maximum width of 1.25 miles. Proved effective closure is 140 feet. Drilling is still in progress. At the northeast end there is some evidence that a fault may bound the field on the southeast side. The initial reservoir pressure was about 2,100 pounds per square inch, or about the same as the hydrostatic head, the average depth of the top of the sand being 5,000 feet. Initial open-flow capacities of the wells ranged from 0.5 to 22.5 million cubic feet of gas per day.

The Woodhull pool, about 11 miles northeast of the Harrison pool, was discovered so recently that its development is still under way. The initial reservoir pressure was 1,950 pounds or somewhat above hydrostatic head, as the average depth of the top of the sand is 4,025 feet. Initial open-flow capacities of the first five wells completed ranged from 12.5 to 26 million cubic feet per day. An early well drilled in the area indicates that a fault bounds the pool on the southeast side.

HEBRON ANTICLINE

In Potter County, Pennsylvania, the Hebron anticline is the next northwest of the Harrison anticline. The Hebron anticline apparently does not extend into New York. The Hebron and the Ellisburg pools,

which are only a short distance apart, have been developed on two elongate domes in north-central Potter County.

HEBRON POOL

The Hebron pool has a length of about 4.5 miles along the axis of the fold and a maximum width of 1.5 miles. The productive area includes approximately 3,800 acres. Effective closure is about 230 feet. One well was drilled into salt water on the northwest flank. On the southeast flank the pool is bounded by a fault. Along the axis of the anticline at the northeast end, a saddle about 2 miles across, which probably does not extend more than 50 feet below effective closure on the two domes, separates the Hebron from the Ellisburg pool. One well drilled in the saddle encountered salt water. On the southwest side, along the axis, production is terminated above the level of effective closure by the wedging-out of the sand.

The finding of gas in the Oriskany in one well about 0.5 mile southeast of the fault near the northeast end of the pool, 260 feet below the lower limit of production in the main pool, suggests the existence of a lower and parallel subsidiary closure similar to the Meaker in the Tioga field, but much smaller. The well had an initial open-flow capacity of 3 million cubic feet of gas per day, but was short-lived.

The initial reservoir pressure of the Hebron pool was 2,160 pounds, or about equivalent to the hydrostatic head, the average depth of the top of the sand being 5,130 feet. Initial open-flow capacities ranged from 2.5 to 65 million cubic feet of gas per day. The ultimate production probably will not exceed 40 billion cubic feet, or an average per acre of 10.5 million cubic feet.[13] The field was developed by 47 wells, of which 36 produced gas, 4 encountered salt water, 4 encountered little or no sand, and 3 were dry holes. In addition, 4 other wells were abandoned before reaching the sand.

ELLISBURG POOL

The Ellisburg dome is not as high as the Hebron, the effective closure being only 125 feet. Salt water was encountered in two wells on the northwest flank. On the southeast side the dome is bounded by a fault, probably a continuation of the fault which occurs on the southeast side of the Hebron pool. The pool has a length of about 6 miles along the axis of the fold and a maximum width of 1.75 miles. The initial reservoir pressure was 2,100 pounds per square inch. The

[13] John R. Reeves, "Hebron Gas Field, Potter County, Pennsylvania," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20 (1936), pp. 1025–26.

average depth of the top of the sand is 5,160 feet. Initial open-flow capacities of the wells ranged from 4 to 38 million cubic feet per day.

STATE LINE FIELD

The State line field is on the Smethport anticline, the next northwest of the Hebron anticline, where it crosses the New York-Pennsylvania line. The State Line field (Fig. 4) is divided lengthwise into two separate pools by a reverse fault dipping northwest, with a maximum throw of almost 200 feet. The field has a length of about 3 miles along

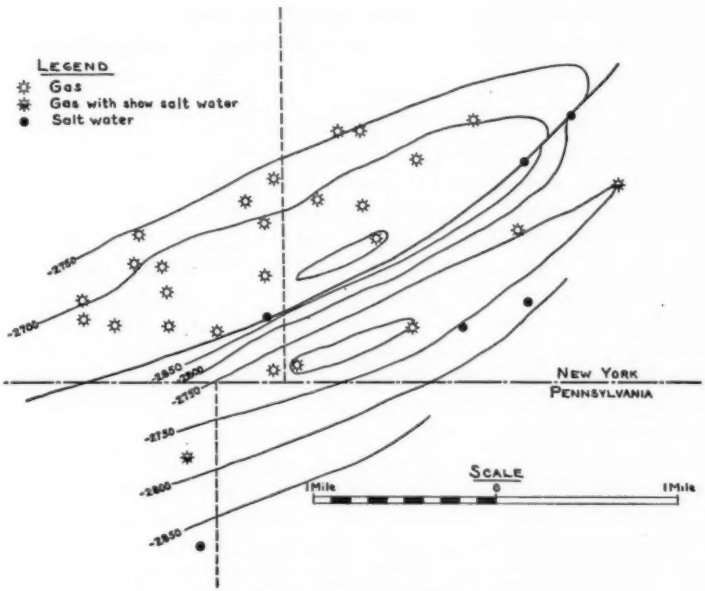


FIG. 4.—Structure map of State Line gas field, New York and Pennsylvania.

the axis of the fold. The northwestern of the two pools has a maximum width of about one mile and an effective closure of 120 feet, and the southeastern, a width of 0.5 mile and an effective closure of 80 feet. The initial reservoir pressure was 2,000 pounds per square inch, or nearly equal to the hydrostatic head, the average depth of the top of the sand being 4,700 feet. Initial open-flow capacities of wells ranged from 4 to 40 million cubic feet per day. Salt water was encountered in three wells drilled on the southeast flank and in three

drilled along the fault. Two wells in the southeastern pool were drilled so near the gas-salt-water contact that they produced considerable water with the gas, and two edge wells on the northeastern flank began producing water at an early stage in the depletion of the pool.

GREENWOOD POOL

Five wells ranging in initial open-flow capacity from 7 to 16 million cubic feet per day have been drilled in a relatively small area in the town of Greenwood, in southwestern Steuben County, New York, about 16 miles northeast of the State Line field, along what is probably an extension of the Smethport anticline. The closure appears to be less than 35 feet. Attempts to extend the productive area have not been successful, as only salt water has been encountered.

WAYNE-DUNDEE FIELD

The Wayne-Dundee field represents the first commercial development of gas in the Oriskany in New York. The field is in northwestern Schuyler, northeastern Steuben, and southern Yates counties, on a dome along the Fir Tree Point anticline, one of the outlying northern Appalachian foreland folds. The dome is elongate east and west, being more than twice as long as wide.[14] It had an effective closure of nearly 90 feet. Two "highs" appear to be developed along it on the Oriskany sand, the western, or Wayne, rising about 20 feet above the eastern, or Dundee. The intervening saddle descends perhaps 20 feet below the crest of the lower structure. No evidence of faulting has been found.

The productive area included approximately 6,000 acres. The initial reservoir pressure of the pool was 730 pounds per square inch, or about equivalent to the hydrostatic head, the average depth of the top of the sand being 1,924 feet. The initial open-flow capacities of the wells ranged from 0.5 to 12 million cubic feet of gas per day. The field is practically exhausted. Almost the entire western part is flooded out and the water has encroached over much of the eastern part.

A unique feature of the field was the occurrence of sweet gas in the western part and sour gas in the eastern part. The saddle separating the two areas was not drilled, and there is a possibility, therefore, that the two parts of the field represent two separate pools. During the later stages in the depletion of the field, some hydrogen sulphide appeared in the wells at the western end, but this is said to have come in

[14] D. H. Newland and C. A. Hartnagel, "Recent Natural Gas Developments in South-Central New York," *New York State Mus. Cir.* 7 (1932), p. 6.
J. French Robinson, Verner Jones, and J. Gaddess, *op. cit.*, p. 15.

from the north and not the east. Hydrogen sulphide has not been encountered in any of the other Oriskany sand pools.

NORTHERN ALLEGANY COUNTY

In the town of Allen, in northern Allegany County, New York, where the Oriskany sandstone wedges out updip, good showings of gas and oil have been encountered in several wells. Only one, however, with an initial reservoir pressure of about 1,300 pounds and an initial open-flow capacity of 1.2 million cubic feet of gas and several barrels of oil per day with only a showing of salt water, could be considered a commercial well. The sand in the surrounding territory is thin and ordinarily yields only salt water.

WESTERN PENNSYLVANIA

In western Pennsylvania thus far only one discovery has been made which gives promise of developing into a commercial pool. This is located in South Beaver Township in northwestern Beaver County. One well drilled to the Oriskany sandstone had an initial rock pressure in excess of 1,890 pounds per square inch and an initial open-flow capacity of 1.5 million cubic feet per day. A somewhat smaller earlier well, 0.8 mile farther west, is also a commercial producer, but the gas is accompanied by some salt water, and a well 1.6 miles northeast produced only salt water. The maximum difference in elevation on the top of the sand in the three wells is only 36 feet.

Two wells in Beaver Township, northwestern Crawford County, encountered good showings of oil along with salt water in the Oriskany sandstone, but did not become commercial producers. A well in Kinzua Township, eastern Warren County, encountered an initial open flow of 0.5 million cubic feet per day but was soon flooded out by salt water. Three other wells in the vicinity encountered salt water. In a strip about 1.25 miles long and 0.25 mile wide, the maximum difference in elevation on the top of the sand as shown by the four wells is only 31 feet.

EASTERN OHIO

Commercial quantities of gas in the Oriskany sandstone in eastern Ohio have been encountered in three localities. The first of these to be exploited is in Ashtabula County in the northeastern part of the state, where the sand is shallowest. Here three small Oriskany sand gas pools were developed during the early part of the present century. They are on the feather edge of the sandstone. Total production was small and the wells were soon flooded out by salt water.

About 1923, gas was encountered in a sandstone 115 feet below the top of the "Big lime," which has since been proved to be the Oriskany, west of Cambridge in Guernsey County. This discovery led to the development of a pool about 12 miles long and 5 miles wide at its widest part. Later, oil of Pennsylvania grade was found in commercial quantities along a narrow belt on the east or downdip side of the pool. Wells of as high as 100 barrels per day initial production were completed, but most of the wells were much smaller. Due to the thinness of the sandstone, less than 12 feet, the total production has not been large. Salt water is encountered in the sand on the lower side of the pool. Accumulation in the Cambridge pool apparently was controlled by a stratigraphic rather than a structural trap. The sand wedges out up the monoclinal slope west of the field. A second pool exhibiting very similar features, but smaller, has been discovered about 8 miles north of the first. These two pools, thus far, are the only pools in which oil in commercial quantities has been obtained from the Oriskany sandstone.

Recently a small gas pool in the Oriskany sandstone has been opened in Madison and Wayne townships in southern Columbiana County. The area developed to date includes about 3 square miles in which 5 producing wells with initial open-flow capacities ranging from 500,000 to 800,000 cubic feet per day have been drilled. Sand thickness ranges from 22 to 28 feet. Salt water has been encountered on the north and east sides of the pool. In one well on the west side the sand was dry. On the south side the limits of production have not been determined. The pool seems to occupy a small structural nose, probably open on the west side in which direction the sand may wedge out in a relatively short distance. A well located 5.5 miles slightly west of south of the pool encountered no sand at the Oriskany horizon.

CONNATE WATER IN ORISKANY SANDSTONE

Analyses of connate waters from the Oriskany sandstone from four widely separated localities are given in Table III. Two analyses of similar waters obtained from Upper Devonian oil sands in Pennsylvania are included for comparison. The Oriskany waters are much more highly concentrated and possess a higher calcium-sodium ratio than the Upper Devonian waters. Otherwise, they are very similar. Carbonates and bicarbonates are absent and the sulphate content is low.

In the north-central Pennsylvania Oriskany pools the gas in nearly all the wells is accompanied by small amounts of fresh water which appears to be present in the gas as a vapor. This has caused some

freezing trouble. In one case in which accurate measurements were made throughout a period of two months, it was found that in two different wells located 0.75 mile apart, each produced 4 gallons of fresh water per million cubic feet of gas.[15] The occurrence of water vapor in the gas seems to substantiate the theory of Mills and Wells that concentration of connate waters has been brought about by the progressive evaporation of water into moving and expanding gas migrating through the sediments.[16]

TABLE III

COMPOSITION OF CONNATE WATER FROM ORISKANY SANDSTONE AND UPPER DEVONIAN OIL SANDS

	1	2	3	4	5	6
Fe	65	2.1	124	144	119	38
Ca	47,200	34,100	49,779	56,004	16,860	14,370
Mg	5,790	4,900	4,966	7,806	2,530	2,118
Na	47,400	50,600	57,967	56,176	38,900	33,800
K	1,276	1,472	3,360		272	203
CO_3	0	0	0	0	0	0
HCO_3	0	0	0	0	0	0
SO_4	2	148	194	166	565	1
Cl	172,500	153,600	198,790	208,078	97,000	84,000
Br	570	500	Not det.	Not det.	540	36
I	1—	1—	Not det.	Not det.	11	9
Total dissolved solids	280,000	248,900	315,449	326,892	158,300	137,300

1. Connate water from Oriskany sandstone, Penn-United Gas Company's Frank Wheeler well No. 1, Tioga field, Tioga Co., Pa. S. K. Love, U. S. Geological Survey, analyst.
2. Connate water from Oriskany sandstone, "Cady" well, Lot 14, near Inavale, town of Wirt, Allegany Co., N. Y. S. K. Love, U. S. Geological Survey, analyst.
3. Connate water from Oriskany sandstone, Fidelity Petroleum Corporation's Ulf well No. 1, near Tidioute, Warren Co., Pa. Charles R. Fettke, analyst.
4. Connate water from Oriskany sandstone, Clyde Fisher's Henry Probst well No. 1, near Osgood, Sugar Grove Township, Mercer Co., Pa. Charles R. Fettke, analyst.
5. Connate water from Bradford Third sand from the Berwald and Odel Oil Company's well No. 1, 0.5 mile west of extreme western edge of tip of southeastern lobe of the Bradford pool, Lafayette Township, McKean Co., Pa. Analyst, U. S. Geological Survey.
6. Connate water from Kane sand from the Sloan and Zook Company's Indian well No. 12, Kane pool, Highland Township, Elk Co., Pa. Analyst, U. S. Geological Survey.

METAMORPHISM

On Figure 2 it may be seen that the Tioga gas field, the most easterly of the Oriskany sand pools in Pennsylvania, is crossed by the 70 isocarb line. Although there have been several tests made on

[15] Frank E. Eckert, "Deep Sand Development in Eastern Area," *Amer. Petrol. Inst. Prod. Bull. 213* (1934), p. 13.

John R. Reeves, *op. cit.*, p. 1027.

[16] R. Van A. Mills and Roger C. Wells, "The Evaporation and Concentration of Waters Associated with Petroleum and Natural Gas," *U. S. Geol. Survey Bull. 693* (1919), pp. 67–68.

equally well defined structures east and southeast in both Tioga and Bradford counties, Pennsylvania, none of them has produced. The Oriskany sandstone was found in every test, but was so tightly cemented and recrystallized that it was no longer capable of acting as a reservoir rock for the retention of fluids.

There is a close relationship between the composition of the hydrocarbon gases in the Oriskany sandstone and the degree of metamorphism of the associated strata. The gas from the Tioga field is a very "dry" gas. It contains 99.5 per cent methane and no higher hydrocarbons.[17] Hamilton, who has made a study of this relationship, has furnished the writer with the following analyses showing the increase in higher hydrocarbons in a northwesterly direction in the north-central Pennsylvania and south-central New York area.[18]

TABLE IV

COMPOSITION OF HYDROCARBON GASES FROM ORISKANY SANDSTONE*

	Tioga Field, Pennsylvania	*Wayne-Dundee Field, New York*	*Town of Allen, Allegany Co., N. Y.*
Methane	99.5	97.2	83.7
Ethane	0.0	1.5	10.4
Propane	—	—	2.8
Butane	—	—	1.1
Pentane and heavier	—	—	0.7

* Point Breeze Laboratory of Atlantic Refining Company, Philadelphia.

Northwest of the 60 isocarb the Oriskany sand gas wells produce appreciable quantities of distillate and casing-head gasoline. The Beaver County, Pennsylvania, and Columbiana County, Ohio, pools are examples. Farthest from the source of the dynamic forces that caused the metamorphism, a paraffine-base, wax-bearing oil is found in some places in the sandstone as witnessed by the good showings encountered in wells in northern Allegany and southeastern Cattaraugus counties, New York, and northwestern Crawford County, Pennsylvania, and the commercial production in Guernsey County, Ohio.

POSSIBLE RESERVES IN ORISKANY

NORTH-CENTRAL PENNSYLVANIA AND SOUTH-CENTRAL NEW YORK

Judged from the results obtained in north-central Pennsylvania, it does not seem likely that any large reserves of gas in the Oriskany sandstone exist in the prominent foreland folds southeast of the

[17] S. H. Cathcart and T. H. Myers, *op. cit.*, p. 24.

[18] S. H. Hamilton, "Oriskany Explorations in Pennsylvania and New York," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 12 (December, 1937), p. 1582.

70-isocarb line. Northwest of that line in south-central New York and north-central Pennsylvania, eight pools that may be considered to be of commercial rank have been opened during the 7 years that have elapsed since gas was discovered in the area in commercial quantities. In each of these, structural rather than stratigraphic traps have caused the accumulation of the gas. In view of the large amount of prospecting that has been conducted in the area, much of which has been based on detailed geological surveys, both surface and geophysical, it does not seem probable that any very large number of additional pools of the rank of those already developed remain to be discovered.

NORTHWESTERN PENNSYLVANIA

In northwestern Pennsylvania the probable existence of a nearly continuous body of sandstone at the Oriskany horizon, which, in parts of the area, retains a fair percentage of porosity, as witnessed by the amounts of salt water encountered in it, is the factor most favorable to the possible occurrence of commercial quantities of gas and possibly oil. On the other hand, the sandstone is probably comparatively thin in the entire area. Large total yields per acre of productive area, therefore, can not be expected even if future prospecting should lead to the development of commercial production.

Most important of all, probably, is the question whether or not there are sufficiently prominent structures present that acted as traps and brought about a segregation from the associated salt water of gas and oil migrating up the monoclinal slope. Typical foreland folds are no longer recognizable. Cathcart's work on the surface geology of Crawford, Erie, and Warren counties, however, has shown that structural noses, terraces, and even gentle domes can be recognized in the outcropping beds.[19]

Convergence between the key beds at the surface and the Oriskany sandstone is of such magnitude, however, as to shift the axes considerably and change the outlines of these minor structural features at the deeper horizon. The results obtained to date in northwestern Pennsylvania have not been encouraging.

SOUTHWESTERN PENNSYLVANIA

The Oriskany sand possibilities of southwestern Pennsylvania are still practically unexplored. The presence of 25 feet of Oriskany sandstone in a well far down the northwest flank of the Chestnut Ridge

[19] S. H. Cathcart, "Geologic Structure of Northern Pennsylvania Has Deep Sand Possibilities of Gas and Oil," *Oil and Gas Jour.* (December 20, 1934), pp. 58–59.

anticline in southeastern Jefferson County and its presence in the well recently completed on the Laurel Ridge anticline in eastern Westmoreland County, as well as its known occurrence in eastern Ohio and in northern West Virginia, indicate that the sandstone is probably present in a large part of the area.

The area can be considered to be bounded on the east by the Chestnut Ridge anticline, along whose axis several prominent domes exist that have not yet been tested. There are also several other less prominent folds west of this anticline that can be readily traced on surface beds for long distances, along which favorable structures exist. The sand under these structures, however, is deep, as shown in Figure 2. Only the one small Oriskany sand pool in Beaver County, which is beyond the area of typical foreland folds, has thus far been discovered in this part of the state.

In closing, the writer wishes to acknowledge the coöperation of the many geologists and operators working in the area under discussion, who so generously contributed the data that made the preparation of this paper possible.

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VOL. 22, NO. 3 (MARCH, 1938), PP. 267-284, 3 FIGS

CHESTER ROCKS OF MEADE, HARDIN, AND BRECKINRIDGE COUNTIES, KENTUCKY[1]

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ABSTRACT

Alternating sandstone, shale, and limestone sediments occur throughout the lower and middle Chester in Indiana and most of Kentucky; however, an abrupt change takes place in the stratigraphic development in the Gasper River region of Kentucky, where the clastic beds of the lower Chester disappear. Although at least three limestone formations in the upper Chester persistently crop out, local abrupt changes in lithologic character of the intervening sediments make difficult a division or description of some of the clastic units. Many of the formations of the Chester series which have been described and named in Indiana and elsewhere are believed to have correlatives in Meade, Hardin, and Breckinridge counties, Kentucky.

INTRODUCTION

Field work and acknowledgments.—Data for this paper are based on work which the writer did at various intervals from 1928 until 1932. A few revisions were made in the manuscript early in 1936 before it was read at the meeting of the Kentucky Academy of Science. Valuable assistance in preparation was rendered by Colonel Lucien Beckner in the office as well as on many trips into the field. R. B. Drescher assisted in almost all of the field work throughout the area and collected a great many of the data. Acknowledgments are due Walter Bucher and George Wesley for criticisms of the manuscript. Finally, the Louisville Gas and Electric Company allowed the writer the time necessary for its preparation, and the writer personally acknowledges his appreciation of the assistance and coöperation extended by these men and the company.

Location.—Meade, Hardin, and Breckinridge counties adjoin and each is bounded on the north by the Ohio River. Hardin County is within 20 miles of Louisville, Kentucky, at its closest point. Meade County is crossed by United States Highway 60, between Tip Top and Irvington; Breckinridge by the same highway between Irvington and Cloverport; and Hardin by United States Highway 31, the main road between Louisville and Nashville, Tennessee.

Name.—The Chester series takes its name from the town of Chester in southern Illinois, having first been used by A. J. Worthen

[1] Read before the Kentucky Academy of Science, 1936, and before the Association at Pittsburgh, October 16, 1937. Manuscript received, November 3, 1937.

[2] Geologist, Louisville Gas and Electric Company.

in a manuscript in 1853. The name Kaskaskia was suggested by James Hall in 1856 for the same bed but, due to complications in nomenclature and the earlier use of Worthen's term, "Chester," it has not been used.

LOWER CHESTER

As set out in the time table (Fig. 1), the Chester series is divisable into three distinct groups, referred to as the lower, middle, and upper Chester. The Chester rocks of Meade, Hardin, and Breckinridge counties have not been satisfactorily described or divided. One reason seems to have been the tendency of the workers to pass over the lower Chester without noting all of its stratigraphic subdivisions

Upper Pottsville		Caseyville cong.
		Unconformity
Upper Chester		Kinkaid ls. Degonia ss. and sh. Clore fm. Palestine ss. Menard ls. Waltersburg ss. and sh. Vienna ls. Tar Springs ss.
		Unconformity
Middle Chester		Glen Dean ls. Hardinsburg ss. Golconda ls. Cypress ss.
		Unconformity
Lower Chester	Paint Creek	*Productus inflatus* zone Elwren ss. and sh Reelsville ls.
		Sample ss.
	Renault	Beaver Bend ls Mooretown ss. Unnamed ls.
		Unconformity

FIG. 1.—Stratigraphic table, Chester rocks, Meade, Hardin and Breckinridge counties, Kentucky.

It is hoped that the use of the Illinois terms Renault and Paint Creek, designating the natural divisions of the lower Chester, will not be confusing when subdivided and the Indiana terminology assigned to the various members. C. A. Malott[3] made the following correlation of the Chester of Indiana and Illinois in 1930.

[3] C. A. Malott, *Proc. Indiana Acad. Sci.*, Vol. 40 (1930), pp. 222.

Indiana	*Illinois*
Negli Creek limestone	Kinkaid limestone
Mt. Pleasant sandstone	Degonia sandstone
Unnamed limestone and sandstone	Clore sandstone
Bristow sandstone	Palestine sandstone
Siberia limestone	Menard limestone
Wyckliff sandstone	Waltersburg sandstone
Unnamed limestone and sandstone	Vienna limestone
Tar Springs sandstone	Tar Springs sandstone
Glen Dean limestone	Glen Dean limestone
Hardinsburg sandstone	Hardinsburg sandstone
Golconda limestone	Golconda limestone
Cypress sandstone	Cypress sandstone
Beech Creek limestone	
Elwren sandstone	Paint Creek formation
Reelsville limestone	
Sample sandstone	Bethel sandstone
Beaver Bend limestone	
Mooretown sandstone	Renault limestone

Divisions of the Renault and Paint Creek in Meade, Hardin, and Breckinridge counties suggest the following correlations which are proposed for the lower Chester.

Kentucky	*Indiana*	*Illinois*
Productus inflatus zone	Beech Creek limestone	
Elwren sandstone and shale	Elwren sandstone	Paint Creek
Reelsville limestone	Reelsville limestone	
Sample sandstone	Sample sandstone	Bethel sandstone
Beaver Bend limestone	Beaver Bend limestone	
Mooretown sandstone	Mooretown sandstone	Renault
Unnamed limestone	Paoli limestone	

It is an accepted fact that the clastic beds of the lower Chester disappear southward and in the Gasper River region the Elwren, which is there a shale, is the only remaining clastic bed of the lower Chester. Additional study has shown that these clastic beds disappear in ascending order and from north to south, the Mooretown first and the Sample second. It is not known whether the Elwren disappears entirely; it is about 3 feet thick at Girkin in Warren County. As these beds disappear, disconformities might naturally be expected between the limestone beds which they normally separate. Contrary to this theory disconformities are not noticed between the limestones of lower Chester age in this region, where the beds are distinguishable by faunal content only, and the upper or lower limits of any of them can be found only with much difficulty. For this reason the Gasper River region has always been the center of much confusion when studying the Chester of Kentucky. If we bear in mind that the clastics reappear both west and northeast of this locality, the interpretation becomes easier and more reasonable. This small area was undoubtedly submerged during lower Chester time and at a maximum

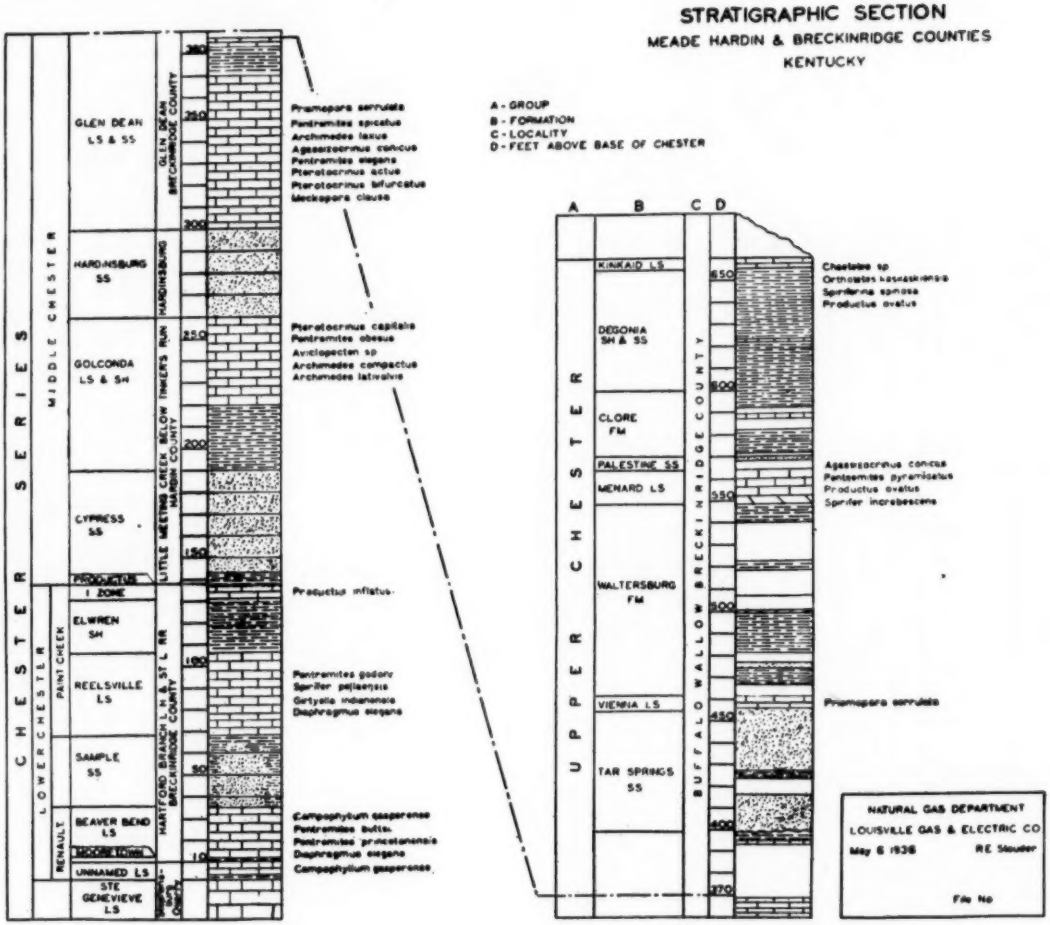

FIG. 2.—Stratigraphic section, Meade, Hardin, and Breckinridge counties, Kentucky.

distance from the land mass, a favorable condition for the accumulation of limestone; while both west and northeast fluctuating water conditions were more prevalent during lower Chester time, and emergence was not uncommon, a favorable condition for the accumulation of sandstone and shale.

Renault.—Weller[4] named and described the Renault formation after studying the section exposed in Renault Township, Monroe County, Illinois, in 1913. In Kentucky it is composed of sandstone, shale, coal, and two limestone members as designated graphically (Fig. 2).

The unnamed limestone at the base of the Chester is excellently exposed at Stephensburg, Hardin County, below the normal position of the Mooretown sandstone at the stone quarry where the following section was taken.

	Feet	*Inches*	
Covered	25		
Limestone	15		Reelsville
Shale	20		Sample
Unconformity			
Limestone	15		Beaver Bend
Sandy banded limestone		8	
Shale		1	
Banded limestone and shale	1	2	Mooretown
Laminated shale	1		
Calcareous sandstone		2	
Shale	2	6	
Dense blue limestone	1		
Sub-lithographic limestone	1	6	
Hard crystalline limestone	3		Unnamed
Shale		1	
Thin-bedded limestone	1	6	
Impure limestone and shale		6	

Below the position of this section, *Platycrinus penicillus* appears. *Campophyllum gasperense* was not found in this limestone. The same bed was observed on the west side of Nolin River at Spurrier's Mill, Hardin County, where it was approximately 23 feet thick, with the bottom of the formation 2 feet below the floor of the bridge. *Campophyllum gasperense* was found from this point to the base of the Sample sandstone, having a vertical range of more than 55 feet. An argillaceous limestone 4 feet thick separates the two Renault limestones at Spurrier's Mill. The unnamed limestone ranges from 0 to 23 feet thick over the three counties.

The terms Ohara and Gasper advocated by Butts were abandoned

[4] Stuart Weller, *Trans. Illinois Acad. Sci.*, Vol. 6 (1913), p. 122.

FIG. 2.—Stratigraphic section, Meade, Hardin, and Breckinridge counties, Kentucky.

by Sutton and Weller[5] in 1932. They published two new names, the Levias limestone to take the place of lower Ohara, and the Girkin, to displace the Gasper oölite. The unnamed limestone at the base of the Chester would naturally become a member of the Girkin, which includes the Renault and Paint Creek of the Gasper River region. Since the name Girkin typifies the exceptional local conditions of the Gasper River region, it seems inadvisable to use it in place of the general designation "lower Chester" in north-central Kentucky, where the sediments are more regionally typical; therefore, the name Girkin has not been included in the time-table.

Throughout Meade and Breckinridge and most of Hardin County a gnarled sandstone, a thin calcareous shale, and a very thin coal are exposed in the hillsides above the Ste. Genevieve limestone, and also overlying the unnamed basal Chester limestone where it is present. These beds disappear somewhere between Spurrier's Mill and the Stephensburg quarry.

In general this formation thickens toward the north; however, erratic thicknesses occur locally where erosion must have taken place prior to its deposition; thus, irregular-shaped depressions developed in the surface of the Ste. Genevieve limestone to be filled later with sandstone and shale of Mooretown age. East of Grandview Church, Hardin County, it has a maximum thickness of 75 feet. One-half mile east of Arch, in the same county, 20 feet of sandstone has been observed, unconformably resting on the Ste. Genevieve limestone. One-half mile north of Dyer, Breckinridge County, a thin coal and several feet of shale were found under more than 25 feet of the sandstone to rest unconformably on the Ste. Genevieve limestone. On the hillsides near Paynesville, Meade County, the formation averages 8 feet in thickness, and weathers to gnarled lumps of sandstone containing many *Lepidodendron* casts and root fragments. The coal ranging from ribbon thickness to as much as 4 inches occurs regularly north of the Hartford branch of the L. H. and St. L. Railroad to the Ohio River.

The Mooretown is the most easily identified of any of the lower Chester clastics and it has been traced into Indiana, where it was described and named by Malott[6] in 1919. The Indiana term is here proposed for the Kentucky formation so widely distributed throughout Meade, Hardin, and Breckinridge counties.

[5] A. H. Sutton and J. Marvin Weller, "Lower Chester Correlation in Western Kentucky and Illinois," *Jour. Geol.*, Vol. 40, No. 5 (July-August, 1932), pp. 432–39.

[6] C. A. Malott, "American Bottoms," *Indiana Univ. Studies*, No. 40, Vol. 6 (1919), p. 9.

Above the Mooretown is a siliceous, ferruginous, coarsely crystalline limestone, which has been placed in the Gasper oölite, and referred to as the Renault limestone, but always undifferentiated. As a matter of fact it is the most regularly occurring formation between the Ohio River and Warren County; yet it has never been named. The limestone becomes purer toward the south and thickens quite in harmony with the general conditions of sedimentation previously outlined. At the Ohio River and as far south as Webster and Lodiburg, both in Breckinridge County, it is only 14½ feet thick; but in the central western part of the Big Clifty Quadrangle, near Mt. Olive Church, it is 38 feet thick. Identifiable characteristics are large *Pentremites pyriformis*, *P. godoni*, *Spirifer leidyi*, and *Chonetes chesterensis*, all of which range throughout lower Chester, with *P. pyriformis* in abundance and *P. godoni* just appearing. This limestone contains more *Campophyllum gasperense* than any other of the lower Chester limestones, and contrary to Sutton's findings, the writer has never found them above the Renault. Another feature of identification is the occurrence of calcium-carbonate crystals irregularly throughout the thickness of the bed in much the same manner and form as the calcite crystals in the Silurian Brassfield formation of Kentucky. It has been traced across the Ohio River into Indiana, where Malott[7] gave it the name Beaver Bend limestone in 1919. It is here proposed that the Indiana name be used to designate the upper limestone of Renault age in Kentucky.

Sample sandstone.—The type section of the Sample[8] sandstone is in Breckinridge County near Sample Station, on the L. H. & St. L. Railroad. It is little different in texture from the other Chester sandstones. The sand grains are sharp, ranging in color from light to dark brown, with both massive and thinly laminated beds. The sand body is wedge-shaped, with the bit toward the Gasper River and the blunt side next to the Ohio River. An erratic change in facies takes place locally, the formation being a pure sandstone 30–35 feet thick and changing to sandy shales in less than 1,000 feet horizontally. A good example of this is exhibited in the Hartford branch of the L. H. & St. L. Railroad at Sinking Creek hill. The sand body changes from a rather fine-grained sandstone, 31 feet thick, to a shale and sandstone in less than 600 feet. There are no infallible characteristics of the Sample sandstone which can be used for identification. The best method is to study the limestones above and below. It is not depend-

[7] *Ibid.*, p. 9.

[8] Charles Butts, "The Mississippian Formations of Western Kentucky," *Kentucky Geol. Survey Pub.* (1917), p. 73.

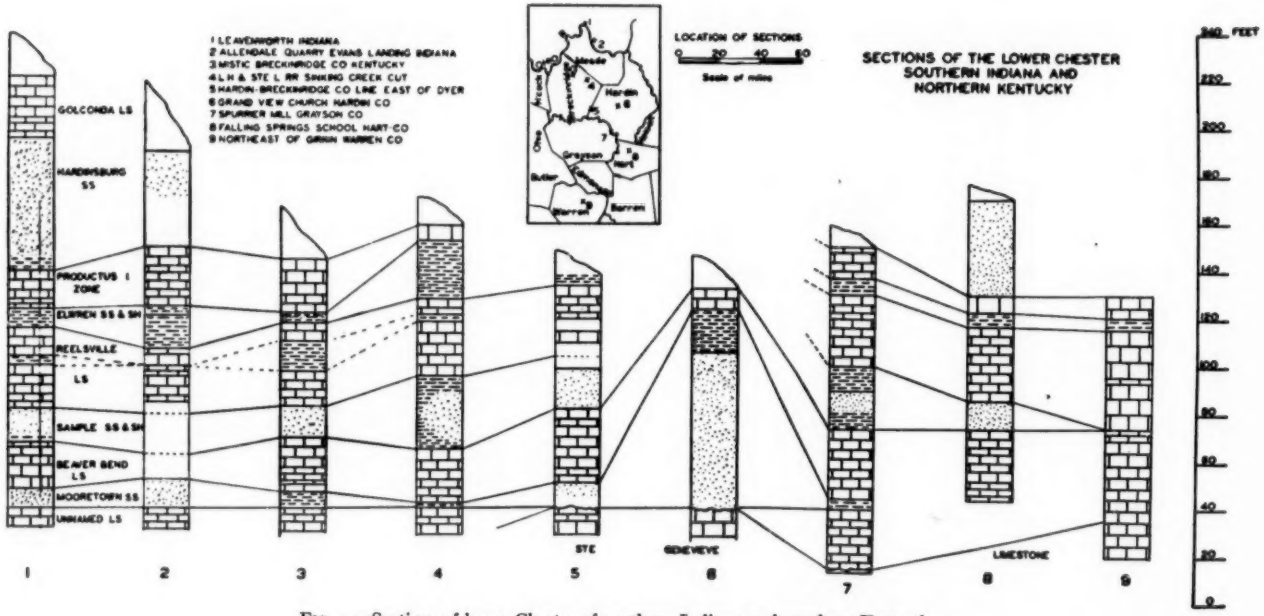

FIG. 3.—Sections of lower Chester of southern Indiana and northern Kentucky.

able because of its wide range of facies. The formation is, without question, equivalent to the Bethel sandstone of Illinois.

Paint Creek.—The Paint Creek[9] is used here to include the group of formations above the Sample sandstone and below the Cypress sandstone between the Ohio River and the southern end of Hardin and Breckinridge counties. The Paint Creek typifies a section of shales and thin limestones in Illinois. The Paint Creek of Meade, Hardin, and Breckinridge counties includes three distinct formations, a basal limestone 30 feet thick, a central sandstone and shale 20–40 feet thick, and an upper limestone member about 8 feet thick, aggregating an average thickness of 62 feet near Lodiburg. All of these formations have formerly been lumped together as the upper Gasper and have not been described in detail. This name is inadequate because it was originally used to describe a local phase in a restricted territory. When applied to a more typical lower Chester section where the significance of this localism is lost, its usefulness ceases because it transgresses a formation complete in itself. The term Paint Creek is much better because it is limited to the upper part of the lower Chester, and because it is the exact correlative of the Illinois section; and, therefore, simplifies the nomenclature and describes areal extent. The three formations of the Paint Creek described here are correlatives of three distinct formations of Indiana, from bottom to top, the Reelsville limestone, the Elwren sandstone and shale, and the Beech Creek limestone. The names of the two lower members are here proposed for the Kentucky formation; while the descriptive term *Productus inflatus* zone, first used by Charles Butts, is here used in the same manner.

The Reelsville limestone was named and described by Malott[10] in 1919. It is the most persistent formation in the lower Chester group with relation to physical characteristics, thickness, and faunal assemblage. It is similar to the Ste. Genevieve formation in texture; in fact they are so much alike that it is difficult, in some places, to distinguish one from the other on the basis of physical appearance. The faunal assemblages are different; *Pentremites godoni* is an index guide in the Reelsville, but is wanting in the Ste. Genevieve. Other fossils occurring in the Reelsville include the following: *Productus elegans*, *Pentremites pyriformis*, *Girtyella brevilobata*, *Chonetes chesterensis*, and *Spirifer pellaensis*.

There is a marked scarcity of fossils at the top of this formation, where the sea floor was undoubtedly subjected to a long interval of

[9] Stuart Weller, *Trans. Illinois Acad. Sci.*, Vol. 6 (1914), p. 125.

[10] *Op. cit.*, *p.* 10.

scavenger action. Experience is valuable in identifying and correlating all of the beds of the Chester, but this is especially true of the Reelsville. The surface of the uppermost bed of the Reelsville is an impure, grayish blue limestone physically similar to the Waynesville of Richmond age. This bed is an excellent key horizon for structural data. A persistent mudstone about 2 feet thick is found about 12 feet below the top, appearing regularly from the Ohio River to the Warren County line. This physical feature is helpful in identification, so long as it is not confused with a comparable bed in the Menard limestone of the upper Chester. The Reelsville is 28 feet thick near Germantown in Breckinridge County. In the Gasper River region it thickens and rests on the underlying Renault with no apparent break in sedimentation. The upper limit is generally marked by a shale or an argillaceous sandstone.

The Elwren sandstone and shale also named by Malott[11] in 1919 separate the two limestones of Paint Creek age. They are widely distributed from the Ohio River to Warren County. Additional investigation may show that the Elwren pinches out entirely between Girkin and the Christian County line. In almost all localities between Richardson's Landing, in Meade County, and Eveleigh's Mill on Rough River in Grayson County, the formation has a few feet of very thinly laminated sandstone, which varies from green to buff in color, and weathers to white slaty flakes. The formation is wedge-shaped and oriented in the same way as the underlying Sample formation. Sandy shale predominates in the Elwren throughout. Like other clastic beds of the Chester, it is not easily identified. The best interpretations can be made by studying the limestones below and above it. The formation is 40 feet thick near Seree in Breckinridge County, and only 3 feet thick at Girkin.

Productus inflatus zone.—The highest member of the Paint Creek has been called by Charles Butts[12] the *Productus inflatus* zone, a descriptive term in place of a geographic name. The *Productus inflatus* zone is typically developed in the southern parts of both Meade and Breckinridge counties and throughout its outcrop in Hardin, Grayson, and Warren counties. Along the Ohio River and in southern Indiana *Productus inflatus* is not nearly so plentiful in the zone below the Cypress sandstone as in Kentucky, where it is the most readily identifiable bed of all the Chester formations. It is a coarsely crystalline, ferruginous limestone and contains an abundance of the fossils for which it is named. Numerous small caverns have been developed by

[11] *Ibid.*, p. 11.

[12] *Op. cit.*, pp. 87–90.

water that filters through the massive overlying Cypress sandstone and issues from springs in the limestone. It ranges in thickness from 4 to 12 feet and is equivalent to the Beech Creek limestone of Indiana. The same bed is found below the Cypress sandstone in Illinois and Tennessee.

MIDDLE CHESTER

An unconformity separates the lower and middle Chester; thus the Cypress sandstone unconformably overlies the *Productus inflatus* zone. The emergence must have been of short duration, since the *Productus inflatus* zone is present regularly in its proper position. Had the emergence been longer, it would have been eroded away in many localities. In general the middle Chester rocks were deposited under fluctuating water conditions. Large rivers deposited sand for a long interval of time; but upon submergence of the land, conditions were favorable for limestone accumulation. As the waters receded, rivers developed and delta deposition followed. Such a cycle of marine environment was contributory to the succession of sandstones, shales, and limestones of the middle Chester.

Cypress sandstone.—The Cypress was named by Englemann[13] in 1868. It is a coarse-grained, dark brown, massive, cross-bedded, cliff-forming sandstone. It is typically exposed along the lower Chester escarpment from Richardson's Landing on the Ohio River to Summit in western Hardin County. It is regularly a sandstone and in few places displaced entirely by shale. In this respect it is quite different from the Sample or Mooretown sandstones, both of which are found as a shale in many places. Several of the higher sandstones can be easily confused with the Cypress and in a few localities it is entirely possible to mistake the Sample sandstone for the Cypress. Like other sandstone formations, it is much safer to identify the Cypress by properly correlating the limestones immediately above and below it. The shale commonly found between the top of the sandstone and the base of the Golconda limestone is normally included in the latter formation in Kentucky, and, on this basis, the Cypress sandstone ranges in thickness from 50 to 70 feet.

Golconda limestone.—The Golconda[14] formation is a coarsely crystalline, dark gray, siliceous limestone at the top, with 15–24 feet of red, blue, and gray shale at the base. The most common characteristic for identification is the abundance of rectangular, white chert blocks in its decomposed and partially weathered outcrop. In many

[13] H. Englemann, *Trans. St. Louis Acad. Sci.*, Vol. 2 (1868), pp. 189–90.

[14] Charles Butts, *op. cit.*, p. 91.

places the chert may be found in the soil where the limestone has completely disintegrated. It is readily soluble in weak acids and numerous sink holes have developed. Water from these sinks issues from the base of the limestone on the hillsides as intermittent springs. The formation occurs regularly and because of its position above the Cypress sandstone, it is the best key horizon for structural work in the middle Chester. Numerous small quarries have been opened throughout Kentucky for road metal and agricultural purposes but, due to the normal over-burden, the Golconda is not quarried as widely as the Glen Dean limestone above. Fossil collections can not be made satisfactorily except in a few of the glade-like exposures. Species of *Archimedes* are in much greater abundance in the Golconda than in any of the underlying Chester formations. *Pentremites obesus* and its associate, *Archimedes compactus*, are two of the best index fossils. *Pterotocrinus capitalis* heads, stem segments, and plates are not uncommon. About 90 fossil species in all have been named and described. The average thickness of the limestone is 30 feet and the average thickness of the underlying shale is 20 feet, aggregating about 50 feet.

Hardinsburg sandstone.—The Hardinsburg sandstone takes its name from the county seat of Breckinridge County, first described by Butts[15] in 1917. It is typically exposed just north of the city limits of Hardinsburg, where the base of the formation is massive and cliff-forming, and the top thin-bedded and slightly flaggy. It occurs persistently but, unlike the Cypress, is not exclusively a sandstone. The rocks dip so gently that it is not uncommon for the plains developed on the Cypress to pass into the Hardinsburg with no visible change, the intervening decomposed Golconda being entirely obliterated. Surface warping is a common characteristic in the Hardinsburg sandstone. This is probably mainly due to the decomposition of the underlying Golconda limestone by chemical action. As the limestone dissolves, the overlying sandstone beds warp to fit the new underlying contour. This is particularly noticeable on gentle hillsides and around karsts developed in the Hardinsburg sandstone. The formation averages 35 feet in thickness.

Glen Dean limestone.—The Glen Dean limestone was so named by Butts, from the town in Breckinridge County.[16] It is exposed on both sides of Daniels Creek, which flows through Glen Dean, as well as throughout a wide area between Hardinsburg and Cloverport, and extends from the vicinity of Stephensport on the Ohio River to Falls

[15] *Ibid*, p. 96.

[16] *Ibid.*, p. 97.

of Rough in the extreme southern part of Breckinridge County. The formation contains an approximately equal amount of shale and limestone, with the latter predominating in the lower part. The limestone is normally coarsely crystalline, varies from grayish blue to brown in color, and is highly fossiliferous. The outcrop can be noticed topographically in passing from the flat-topped Hardinsburg plains into the gently rolling Glen Dean area, with the eastward margin marked by a chain of low hills. The width of the outcrop ranges from ½ mile to 5 miles. Many fossils are imbedded in the limestone, but they do not weather out well. *Pentremites spicatus* and *Prismopora serrulata* are two of the most typical fossils. The following fossils are very common.

Fenestella compressa
Archimedes swallovanus
Productus ovatus
Diaphragmus elegans
Spiriferina spinosa
Aviculopecten baldwinensis
Prismopora serrulata
Pentremites spicatus
Archimedes laxus

According to the record of a well drilled on the west side of the creek at Glen Dean, the formation is 102 feet thick. The greater part of the beds is exposed on the hillside below the well and at least the top of the section agrees with the well record. The following section gives an idea of the thickness of the formation.

	Feet
Hard blue limestone	4
Soft blue and green shale	11
Sandy limestone	3½
Green, brown, and blue shale	14
Coarsely crystalline limestone (drilling record)	70

This section is thicker than the average, the normal thickness being more than 60 feet in Breckinridge County. The two thin limestones near the top are difficult to find on the outcrop, and the shale makes a poor marker for structural work. The base of the Glen Dean limestone is a much better datum plane than the top.

UPPER CHESTER

An unconformity separates the middle and upper Chester. At the type section of the Glen Dean limestone, 30 feet of shale is between the limestone proper and the Tar Springs sandstone. This shale contains a plentiful supply of iron which stains the outcrop red when oxidized. Two miles west of Glen Dean the Tar Springs sandstone lies directly on the limestone member of the Glen Dean. The simple alternation of limestones and clastics is lost in the upper Chester; therefore it is a group which does not lend itself to subdivision; however, at least three fairly regular limestones are present among the

many separate units. The total thickness of more than 300 feet of strata is made up mostly of shales, sandstones, and argillaceous limestones, which change in character in extremely short distances. Single units are not easily recognized either in their limits or physical features. In fact, the clastics are fillers between outstanding limestone members. The sandstones are more persistent than the shales and they have been named rather than the shale intervals. The upper Chester of Kentucky has been divided into the following units.

Kinkaid limestone
Degonia sandstone
Clore limestone and shale
Palestine sandstone
Menard limestone
Waltersburg sandstone
Vienna limestone
Tar Springs sandstone

All of these names are used by the Illinois Geological Survey and have been generally accepted by the workers in Kentucky. The succession of sandstones and shales between the Menard and Kinkaid limestones is so erratic that it is almost impossible to distinguish one formation from the other without first referring to the Menard limestone below or the Kinkaid limestone above. These clastics might better be considered as an interval between the two outstanding limestones of upper Chester age.

Tar Springs sandstone.—The Tar Springs sandstone was named by Owen[17] in 1857, but was not given a permanent place in the stratigraphy of the upper Chester until 1917, when Butts[18] made a study of the Mississippian rocks of western Kentucky. The name is taken from the tar springs, 3 miles south of Cloverport, where petroleum-bearing springs issue from near the base of the massive sandstone. It is generally a fine-grained, cross-bedded sandstone, and is 40 feet or more in thickness. The iron concretions which it contains stand out on the weathered surface. Between Glen Dean and Cloverport the Tar Springs averages 55 feet in thickness.

Vienna limestone.—The Vienna limestone was named by Weller[19] in 1917 from the exposures of the formation in the vicinity of Vienna, Johnson County, Illinois. It is normally a siliceous, impure, cherty limestone with 5–10 feet of calcareous shale at the top. A rectangular chert residuum from the limestone is very resistant to weathering and marks the interval of the formation in some places where no limestone

[17] D. D. Owen, *Kentucky Geol. Survey Second Rept.* (1857), p. 87.

[18] Charles Butts, *op. cit.*, pp. 103–05.

[19] Stuart Weller, *Jour. Geol.*, Vol. 28 (1920), p. 396.

is present. The chert is comparable with that in the Golconda formation, except that it is more vitreous and contains very few fossil remains. The Vienna is thin and the outcrop of the formation is negligible in width. It is exposed from the bluff of the Ohio River 2 miles south of Cloverport irregularly to McQuady, Breckinridge County, and thence in a generally southward direction to Rockvale and on to Rough River. It is one of the three persistent limestone beds of the upper Chester formation. Fossils are relatively scarce and their range extends beyond the limits of the formation. The limestone is 10 feet thick at Rockvale and the shale above it is 5 feet thick, making 15 feet in all, which is representative of the entire area. The top of the Vienna limestone is about 80 feet above the Glen Dean. The Vienna is equivalent to one of the yellow, unnamed limestones occurring in the shale beds between the Tar Springs and Wickliff sandstones of Indiana.

Waltersburg sandstone.—Weller[20] named the Waltersburg from a locality in Pike County, Illinois, in 1920. Whether the name should be applied to the sandstone and shaly formations between the Menard and Vienna limestones is not yet positively determined. Two miles northwest of McQuady the shale and sandstone are displayed. This sandstone bed below the Menard limestone is regularly about 12 feet thick. It is noticeably jointed and large blocks slide down the hillsides. The formation weathers very slowly and stands out bench-like below the limestone. Two miles west of Glen Dean, on the Fordsville road, there is a good exposure. It also crops out on the hillside south of Highway 60 about 2 miles south of Cloverport, where it is 30 feet below the Menard. The interval between the Menard and Vienna limestones averages 75 feet. The shale and sandstone in the basal 30 feet are so variable that description is useless; and, with the exception of the sandstone near the top of the interval, there are no regular characteristics which can be used in identification. The top of the Waltersburg interval is generally 145 feet above the top of the Glen Dean limestone.

Menard limestone.—The name Menard was also supplied by Weller[21] where he found it typically exposed in the Mississippi River bluffs just below Menard, Randolph County, Illinois. Butts[22] disposes of the formation by considering the upper Chester compositively and describes a few localities where it is exposed. The Menard limestone is 20 feet thick in the hills west of McQuady. It contains a mudstone,

[20] *Ibid.*, p. 389.

[21] Stuart Weller, *Trans. Illinois Acad. Sci.*, Vol. 6 (1914), p. 128.

[22] Charles Butts, *op. cit.*, p. 113.

near the middle. In this respect, as well as lithologically, it is similar to the Reelsville of lower Chester age. It is the most nearly uniform bed of the upper Chester south of the Ohio River and north of Warren County. As a rule, it varies from gray to dark blue in color, and is dense or compact in texture. The beds are thin, ranging upward from 6 inches with undulatory bedding planes. This limestone decomposes into slabs which slide down the hillsides where they are commonly found out of place below the outcrop. The mudstone near the middle of the formation is the best stratigraphic marker of the bed and, therefore, is an excellent key bed for structural work, ordinarily being less than 20 feet thick and present throughout the outcrop wherever its interval is exposed. Butts[23] listed the fauna found in Breckinridge County from this formation. *Agassizocrinus conicus*, *Pentremites pyramidatus*, *Productus ovatus*, and several species of *Spirifer* are the most common fossils which he lists. The interval from the top of the Glen Dean to the top of the Menard limestone is about 170 feet.

Palestine sandstone.—The Palestine was first described by Weller[24] as occurring in Palestine Township, Randolph County, Illinois. The 95 feet of rocks between the Menard and the bottom of the Kinkaid limestone seem to have no regularity in Breckinridge County. Examination and careful consideration of the entire section show that this interval has three distinguishable subdivisions. For instance, at the well known Buffalo Wallow section, 2 miles southwest of Cloverport, the following rocks crop out.

Pennsylvanian sandstone on top of hill

	Feet	
Shale, blue green	6	
Limestone	3	(Kinkaid)
Shale, variably colored	52	(Degonia sandstone interval)
Shale and limestone mixed	20	(Clore)
Sandstone, thin, quartzitic	2	(Palestine)
Shale, greenish	6	
Limestone, shale, and marl	17	(Menard)

In this locality the upper Chester is practically all exposed, and each bed is easily referred to the top of the Glen Dean limestone, since the latter is exposed about 30 feet above low water in the Ohio River. The thin representative of the Palestine sandstone is quartzitic and occurs regularly southward, constituting the flaggy sandstone found on the hillsides in the vicinity of McQuady. It is also well exhibited on the road between Rockvale and Vanzant. This sandstone is in

[23] *Ibid.*, p. 115.

[24] Stuart Weller, *Trans. Illinois Acad. Sci.*, Vol. 6 (1914), p. 128.

few places more than 6 feet thick, and the entire interval nowhere exceeds 15 feet.

Clore formation.—Weller[25] first described the Clore in Randolph County, Illinois, as the highest known Chester formation, but later demonstrated two higher units. As already noted, in the Buffalo Wallow section near Cloverport there is a limestone and shale interval above the Palestine sandstone. If this section were given in more detail, the predominance of shale would be easily seen. At least 15 of the 20 feet are shale, which separates thin beds of impure limestone, which varies from yellow to bluish black in color. The uppermost member of the bed is a brecciated limestone 4 feet thick. The Clore formation, because of its clay-like texture, makes a very poor exposure throughout Breckinridge County. Outcroppings of marl beds between Falls of Rough and Fordsville, along the steep hillsides, are probably of Clore age. Several miles west of Glen Dean, on the old Frank Dean farm, the Clore is exposed on a hillside west of the residence. The only section measured is at Buffalo Wallow, where the Clore is 20 feet thick.

Degonia sandstone.—The Degonia sandstone was first described by J. M. Weller[26] as occurring in Jackson County, Illinois. Since it is the policy of the writer to adapt names to formations and intervals where possible, it is here suggested that the 50–55 feet of argillaceous sandstone be referred to as the Degonia member. At the Buffalo Wallow section the interval is a varicolored shale from top to bottom, noticeably lacking in marl beds. At Tar Fork Post Office, 30 feet of blue, olive, and maroon shale lie below the Kinkaid limestone. Below the shale an argillaceous, thin-bedded sandstone appears which undoubtedly occupies the Degonia interval. One mile above Height's Falls, on the Leitchfield road, the Degonia crops out at low water in Rough River. The interval rarely exceeds 55 feet.

Kinkaid limestone.—Weller[27] named the Kinkaid limestone after finding the excellent exposures along Kinkaid Creek in Jackson County, Illinois. In western Kentucky the Kinkaid is found regularly in its proper position as blue, crystalline limestone layers except where it was eroded before Pennsylvanian time. Its unweathered exposures vary from thick-bedded to massive. When sufficiently weathered, the bedding planes are more pronounced and their unevenness is at once noticeable. Many excellent exposures occur throughout western Breckinridge County. The best and most accessi-

[25] *Ibid.*, p. 129.

[26] J. M. Weller, *Jour. Geol.*, Vol. 28 (1920), p. 403.

[27] Stuart Weller, *Jour. Geol.*, Vol. 28 (1920), p. 405.

ble outcrops are at Buffalo Wallow, Tar Fork Post Office, the railroad bridge ½ mile east of Fordsville High School in Ohio County, and on the Anderson Richardson farm near Height's Falls. This limestone is fossiliferous, with a colony coral, probably a *Chaetetes*, predominating and an abundance of bryozoans near the base. The Kinkaid is the highest known limestone formation in Breckinridge County; but the shale between it and the unconformably overlying Pottsville formation is very probably of Chester age. The Kinkaid limestone is ordinarily less than 20 feet thick. The interval between the top and the underlying Glen Dean, at the Buffalo Wallow section, has been measured as 275 feet. The accumulated thickness of the beds cropping out between Glen Dean and Tar Fork, falls short of this total by less than 20 feet; hence it is concluded that the thickness of the upper Chester between Rough River and the Ohio River ranges from 250 to 275 feet.

UNCONFORMITY

A long period of erosion undoubtedly ensued between the deposition of the highest known rocks of Mississippian age and the lowest known rocks of Pennsylvanian age in Breckinridge County. For instance, in Alabama the Parkwood[28] formations of Mississippian age, younger than the Chester sediments of the Ohio Valley, are 2,000 feet thick. Above the Parkwood, 10,000 feet of Pottsville,[29] all older than the oldest in the Ohio Valley, were deposited. During the time required for this extensive deposit, the Chester rocks of the Ohio Valley must have been above water and subjected to all of the agencies of weathering and erosion, in the same manner as the land areas of today. Stream patterns were cut into the surface of these upper Chester rocks, and there is no way of determining how many feet of rock were actually eroded during the long emergence. When the Chester area was again submerged, during Pottsville time, the sediments found an uneven surface to rest on, which is well demonstrated in this area. For instance, at Victoria the Pottsville rocks rest on the Kinkaid limestone; at Fordsville the same two formations are separated by 20 feet of shale; farther south, in Warren County, the Pottsville rocks rest on the Golconda; and toward the north, in Indiana, the Pennsylvanian rocks rest on successively older beds and finally the Chester sediments are absent. From these facts we may conclude that the area between the Ohio River and Rough River was subjected to less erosional action than the territory either north or south.

[28] Charles Butts, *U. S. Geol. Survey Geol. Folio 175* (1910).

[29] Charles Butts, *U. S. Geol. Survey Bull. 431* (1911).

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GEOLOGY OF TEPETATE OIL FIELD, ACADIA PARISH, LOUISIANA[1]

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ABSTRACT

The Tepetate field, located in the Gulf Coast area of Louisiana, was discovered by the Continental Oil Company in July, 1935. The presence of a structure was first indicated by a gravity minimum found by the Tepetate Oil Company. The producing sand, encountered at an average depth of 8,300 feet, occurs in the lower *Marginulina* zone. This zone has been assigned to the Middle Oligocene, but more recently considered to be of Lower Miocene age. The Tepetate field is a deep-seated salt-dome structure, with at least 250 feet of closure at the producing level. No faults have been found crossing the field proper; however, faults with considerable displacement were established north and east of the field, thus indicating that the present outline of the dome may be only a part of a much larger structure. The productive area embraces approximately 1,200 acres.

INTRODUCTION

The Tepetate field possesses many unique features which, in the opinion of the writers, make it particularly valuable for a detailed geological study. While this paper should not be considered a final presentation of the problems involved, there is already a considerable amount of data available which should be a valuable contribution to the geological knowledge of the Louisiana Gulf Coast. Thus the writers present in this paper only facts and those interpretations of the facts which seem most applicable at the present time.

The writers wish to express their appreciation to the management of the Continental Oil Company for permitting the publication of this paper.

LOCATION AND PHYSIOGRAPHY

The Tepetate field is in the northeast part of Acadia Parish, Louisiana, centering around Secs. 28 and 29, T. 7 S., R. 2 W. (Fig. 1). It lies in the Gulf Coast salt-dome province and is about 90 miles from the coast line of the Gulf of Mexico and about 18 miles north of the town of Jennings. The nearest oil field, the Evangeline field, is 12 miles south, although a recently completed distillate well about 10 miles west possibly indicates a new and closer field.

[1] Read before the Association at Los Angeles, March 18, 1937.

[2] District geologist, Continental Oil Company.

[3] Geologist, Continental Oil Company.

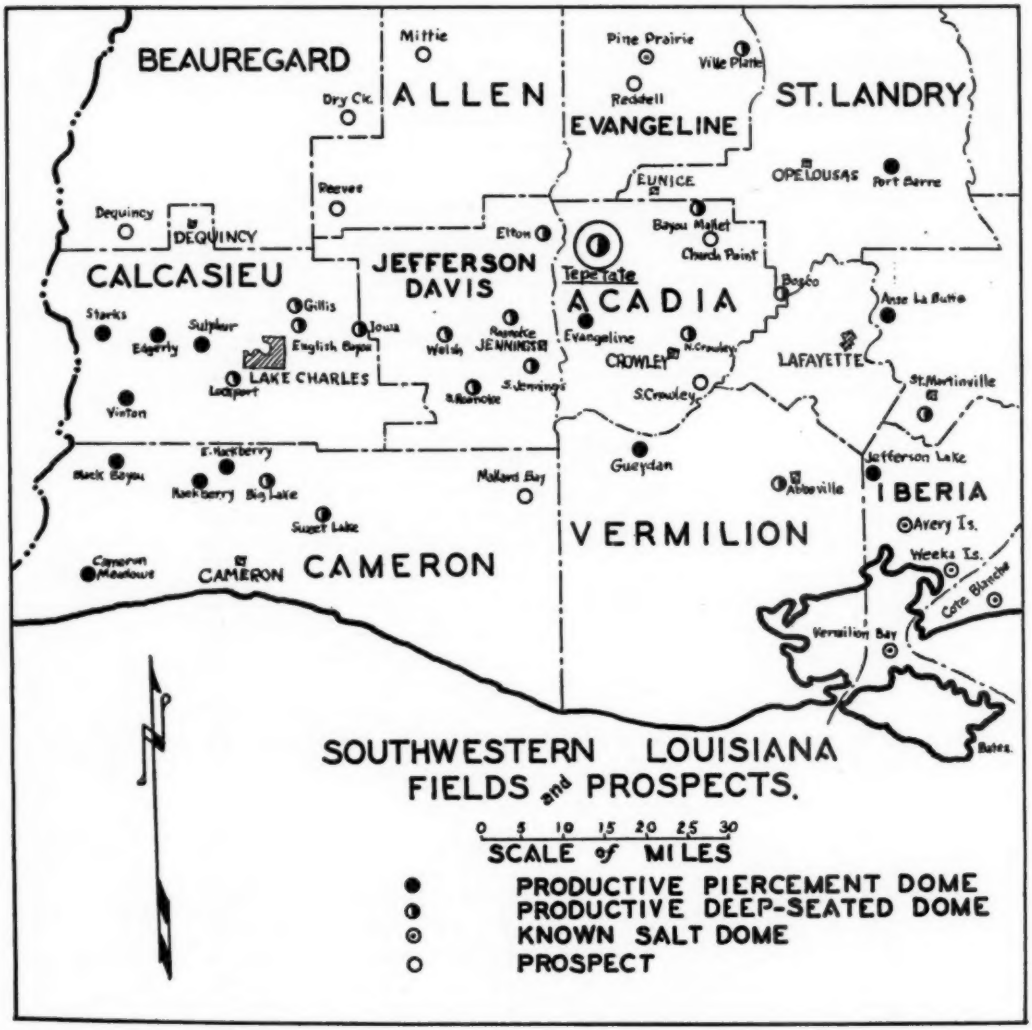

FIG. 1.—Sketch map of southwestern Louisiana, showing relation of Tepetate to adjacent fields and prospects.

The terrane of the Tepetate field is essentially flat, varying between 30 and 45 feet in elevation above sea-level. Bayou Nezpique, 3 miles west, and Bayou des Cannes, immediately east, drain the area, and lower the ground elevations along their courses to about 20 and 25 feet respectively. Cleared land covers the surface of the field proper, in cultivation of rice and cotton. The surrounding country is timbered with oak and pine predominating. The surface formations are principally brownish yellow sandy clays of Pleistocene age. Here and there strips of red clays are observed, but no apparent surface reflection of structure can be found. Likewise, no oil or gas seeps, "paraffine dirt," or other surface clues indicating the presence of an oil field have been detected.

DISCOVERY AND GEOPHYSICAL HISTORY

The discovery and subsequent development of the field are creditable solely to the application of geophysics. The presence of a structure was first indicated in 1930 by a reconnaissance torsion-balance survey conducted by the Tepetate Oil Company (after which company the field was named) under L. L. Welch. Although considerable work was done at this time, no leases were taken until 1933, at which time the same company reworked the area and located a prominent gravity minimum centering in Sec. 34, T. 7 S., R. 2 W. A lease block was then assembled covering the newly discovered prospect. The writers have the permission of the Tepetate Oil Company to include in this paper the isogam map of their original torsion-balance survey (Fig. 2).

The area was detailed in October and November, 1933, by a consulting reflection-seismograph crew, but this work seemed to place the structure considerably south of the torsion-balance picture. The Tepetate Oil Company preferred to credit the torsion-balance location, dropped this southern acreage and leased the present block to the Continental Oil Company for development. The Continental Oil Company reflection-seismograph crew under Donald Beeth surveyed the block in detail during June, 1934, and March and April, 1935, employing entirely the dip-shooting method. This survey indicated the presence of a domal structure of about 400 feet of closure centering in Secs. 28 and 29, T. 7 S., R. 2 W. No major faulting on this structure was established; however, the seismic records distinctly indicate an unconformity at the approximate level of the main producing sand, which was later confirmed by geological subsurface data. The dip-contour map of the original reflection survey is shown in Figure 3. The dip values used in preparing this map were determined

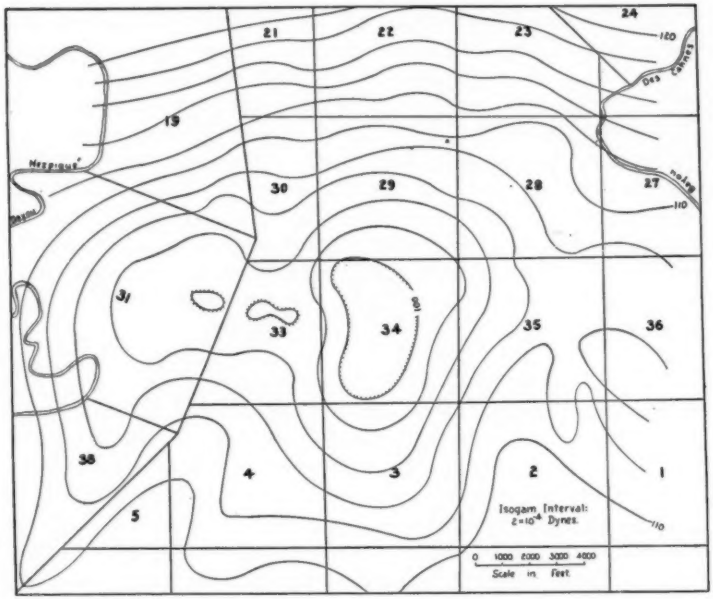

FIG. 2.—Original torsion-balance map of Tepetate field by Tepetate Oil Company.

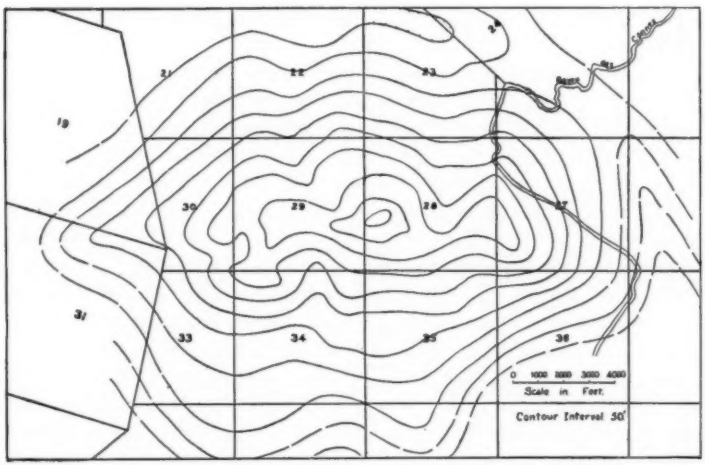

FIG. 3.—Seismograph-contour map of Tepetate field.

by averaging several dips from each individual record through a zone approximately 8,500 feet in depth.

DRILLING DEVELOPMENT

The Tepetate field has been developed entirely by the Continental Oil Company, which controls all productive and contingent acreage. For this reason it has been possible to lay out and follow a very definite plan of development.

The discovery well was spudded, May 9, 1935, in the center of the T. Ortego 80-acre tract in Sec. 28, T. 7 S., R. 2 W. On July 20, 1935, an oil and gas sand was cored from 8,278 feet to 8,303 feet, at which depth 7-inch casing and screen were set. The well came in making 15 million cubic feet of wet gas under ¾-inch choke, with tubing pressure of 2,750 and casing pressure of 3,100 pounds. The well was subsequently killed and deepened to 8,313 feet in oil sand, where it was recompleted on August 22, 1935, producing 456 barrels of pipe-line oil daily through ¼-inch choke, with tubing pressure of 2,450 pounds and casing pressure of 3,100 pounds, gravity 36.4° corrected, and making 2,318,400 cubic feet of gas (gas-oil ratio 4200:1).

Since the completion of the discovery well the Continental Oil Company has drilled 60 additional wells, only 4 wells being completed as dry holes. Also the Loffland Brothers Company drilled 2 dry holes on the east edge, on the Mrs. L. C. Bowles tract; and the General Crude Oil Company drilled a dry hole on the M. L. Vincent tract 1 mile west of the field. Seven wells were drilled below the main producing sand (8,300 feet), but the others were completed at an average depth of 8,317 feet.

The practice on the early wells was to set 7-inch O.D. casing, screen, and liner. For a time 5¾-inch O.D. casing was set on bottom and gun-perforated opposite the oil sand. A more efficient and economical setting has been found to be 5¾-inch O.D. casing with full-hole cementer, 30 inches of slotted pipe and an 18-inch float guide-shoe set to bottom. Ten and three fourths-inch O.D. surface casing is set at about 1,500 feet. The wells are usually drilled to 1,500 feet with 5-inch drill pipe, to the total depth with 4-inch, and are drilled in with 3-inch flush-point drill pipe. The average time for rigging up, drilling, and completing a well in the 8,300-foot sand is about 26 days.

A spacing program of one well to a 20-acre plot measuring 660 by 1,320 feet has been adopted and rigidly followed.

The field was rapidly developed with the use of the most modern and up-to-date equipment and methods. Electrical-logging surveys were made of every well for geological information. The producing

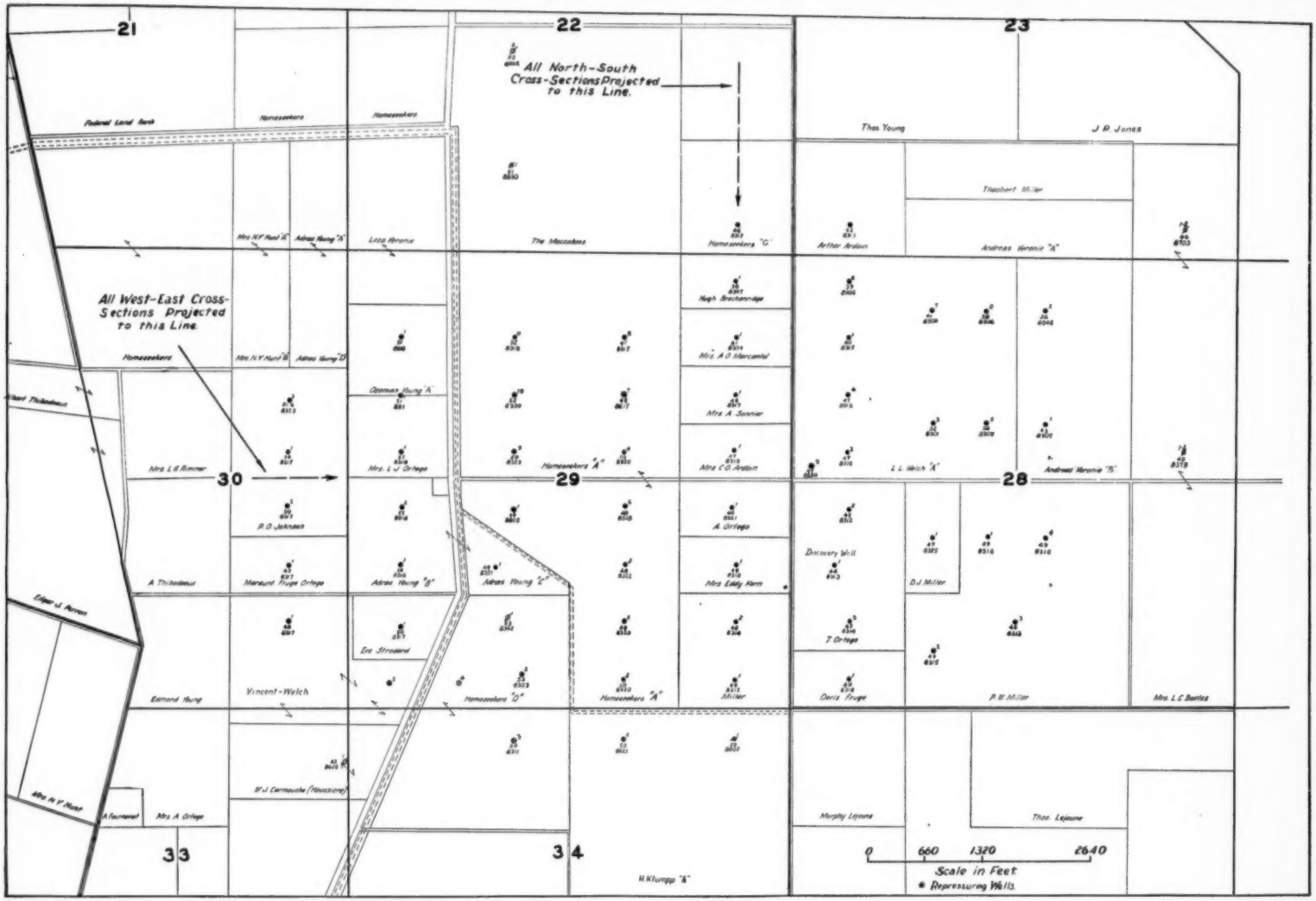

FIG. 4.—Development map of Tepetate field, showing lease ownerships and location of cross sections.

area to date covers approximately 1,200 acres, thus making the Tepetate field one of the largest oil fields of southern Louisiana in areal extent.

STRATIGRAPHY

A generalized stratigraphic section showing the formations penetrated in the Tepetate field is presented in Figure 5.

As already noted, there is found on the surface a sandy clay which is assigned to the Pleistocene. Formations of the same age, consisting of alternating clays, sands, and gravel beds, extend down approximately 1,400–1,500 feet. From this depth down to at least 8,350 feet, the section is considered to be Miocene in age, the uppermost part possibly being Pliocene. Due to incomplete geological information on the shallow formations, the Pleistocene-Pliocene and the Pliocene-Miocene contacts can not definitely be established in this field. The Quaternary-Tertiary contact is tentatively placed at the base of the gravel series.

The subsurface Miocene section of southern Louisiana has been divided into different formations and zones, with lithologic and faunal characteristics as a basis for their distinction. Most of these formations and zones were also recognized in the Tepetate field. From about 1,500 feet to 3,000 feet there is encountered a series of bluish green clays and medium-to-coarse soft sands, here and there containing abundant shell fragments among which are found fragments of *Rangia johnsoni*, an Upper Miocene pelecypod. From 3,000 feet to about 3,700 feet, a series of red and greenish clays and shales, alternating with medium-grained sands, is penetrated. This zone contains *Potamides matsoni*, which gastropod first appears at approximately 3,500 feet. The section between 4,000 and 5,500 feet consists predominantly of medium-coarse and coarse sands, red clays, and grayish lignitic shales, the latter becoming somewhat more abundant in the lower part. The base of this series is marked by a characteristic coarse sand, containing small gravel. The Miocene section so far described is correlated with the Fleming of the Gulf Coast section. The section extending to the base of the producing sand at about 8,350 feet is considered to correspond with the Catahoula.

While the sediments of the Fleming section are predominantly of lagunal and non-marine origin, the beds below, representing the Catahoula series, show an increasingly more marine character until a typical shallow-marine facies is reached at about 6,850 feet. This gradational section consists of green-gray lignitic shales, medium, partly calcareous sands and sandstones. A prominent *Ostrea* bed is

FIG. 4.—Development map of Tepetate field, showing lease ownerships and location of cross sections.

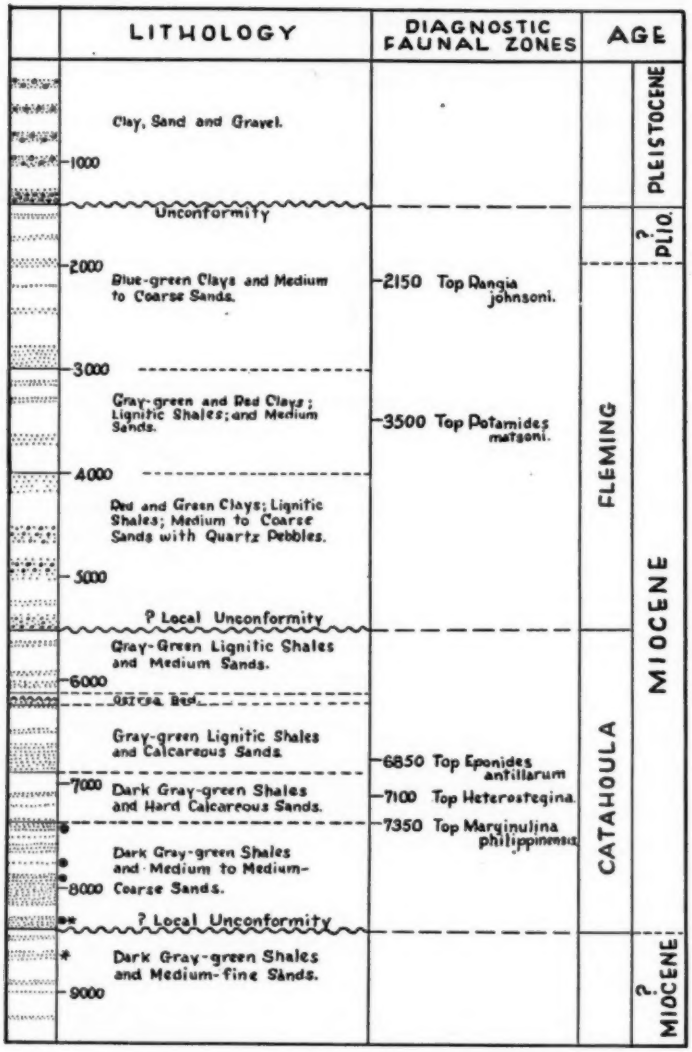

FIG. 5.—Generalized columnar section of formations encountered at Tepetate.

encountered at an average depth of 6,250 feet, in the middle of this section. The basal 300 feet contains a sparse microfauna with a small variety of *Discorbis candeiana*. From 6,850 feet down to the top of the main producing sand, the stratigraphic section consists of predominantly shallow-marine deposits with some near-shore deposits in the lower section. It consists of dark green-gray, brittle, fossiliferous and here and there lignitic shale, hard and soft calcareous sand and sandstone.

There are three distinctive micro-faunal zones present in this particular section. The first zone is characterized by *Eponides antillarum* and a large, beaded variety of *Robulus*. The rare occurrence of a *Heterostegina* sp. indicates that this zone corresponds with the upper part of the *Heterostegina* zone of the Gulf Coast section. The second zone is determined by the abundant appearance of different species of *Heterostegina*, with which is associated an abundant and characteristic micro-fauna. The top of this faunal zone is placed at an average depth of 7,100 feet in the field. It coincides with the top of a very highly calcareous section, easily distinguished on electrical logs; therefore, this top is an excellent correlation marker. The third zone is characterized by *Marginulina philippinensis* (possibly *Marginulina mexicana*); however, since this marker is rather rare in the Tepetate field, the top of this zone is usually determined from the electrical logs. The *Marginulina* zone consists of four distinctive sand bodies which are separated by shale bodies about 100–150 feet thick. The deepest of these sand bodies is the main producing sand of the Tepetate field, here designated as "Ortego" sand. In Klumpp No. 1, in which well the full Ortego sand section was cored, it was found that the basal part of this sand body consists of coarse sand with reworked shale and small pebble inclusions, suggesting a local unconformity at the base of the Ortego sand.

The *Discorbis*, *Heterostegina*, and *Marginulina* zones have in the past been assigned to the Middle Oligocene; however, more recent investigation, particularly by Howe of Louisiana State University,[4] tends to show that these zones may actually be of Miocene age. Due to the apparently continuous sedimentation and the close faunal and lithologic relation of these zones with the overlying beds of unquestioned Miocene age in the Tepetate field, the writers are inclined to support the correlation as suggested by Howe. However, they fully realize that additional paleontological work is necessary to definitely prove this correlation.

[4] H. V. Howe, "Review of Tertiary Stratigraphy of Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 6 (June, 1933), pp. 615–56.

The few wells which have been carried below the main producing level encountered a sedimentary series with lithologic characteristics somewhat similar to those of the *Marginulina* zone except that ordinarily the sands are finer-grained and are considerably thinner than the sand beds in the *Marginulina* zone. In the lower part it contains a good micro-fauna, which has been tentatively determined by Howe as being Lower Miocene in age. The senior writer also considers the possibility that this section might represent an Upper Oligocene formation, occurring above typical Vicksburg and not represented at the outcrop.

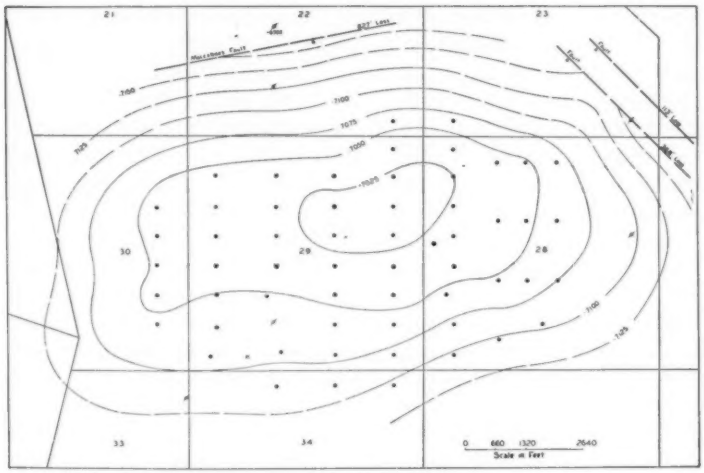

FIG. 6.—Structural map of Tepetate drawn on First *Heterostegina* limestone. Contour interval, 25 feet.

On summarizing the stratigraphy of the Tepetate field in its chronological events, it is seen that according to the oldest geological records a shallow-water marine condition prevailed during the early Miocene (or late Oligocene) time. As there is evidence of an unconformity at the base of the *Marginulina* zone, marking a depositional break, it can be assumed that either this early Miocene sea receded from the area, or, what seems more likely, a local pre-*Marginulina* rise of the sea bottom occurred, thus causing favorable conditions for the deposition of the rather coarse basal *Marginulina* sand which has the appearance of a beach deposit. Evidently, the shore line then oscillated back and forth during *Marginulina* time, producing an

alternation of shallow-water lagunal deposits with shallow-marine sediments. The tendency evidently was to move the shore line farther inland after each short recession. During *Heterostegina* time, the area passed through a period of relative stability, shallow-marine conditions prevailing. With the beginning of the *Eponides* time, the sea began to recede slowly, the marine deposits changing successively into near-shore, lagunal, and finally into non-marine deposits. During this long time of recession, brief transgressions of the Miocene sea occasionally occurred. An evidence of such transgression is the *Potamides matsoni* zone, whose sediments have a more strictly marine

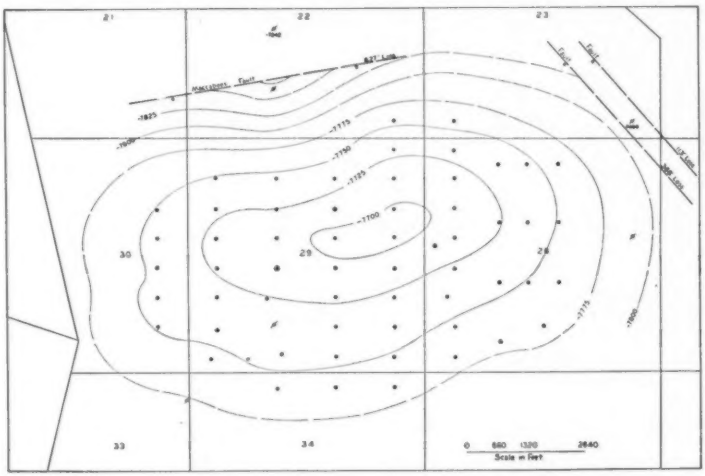

FIG. 7.—Structural map of Tepetate drawn on Welch (Third *Marginulina*) sand. Contour interval, 25 feet.

aspect than the directly underlying older beds. At the end of Tertiary time the sea had completely left the area and the continental Pleistocene gravel and sands were laid down on the old Tertiary land surface.

SUBSURFACE STRUCTURE

The presence of a pronounced gravimetric minimum south of the Tepetate field leads to the belief that the Tepetate structure is the result of a deep-seated salt intrusion, which caused a gentle folding of the overlying shallower formations. The structural configuration of the field at different levels through the Catahoula series is illustrated by three contour maps. The first map (Fig. 6) is contoured on top of

the *Heterostegina* zone with a 25-foot interval at an average depth of 7,100 feet. It shows at this level a very flat oval dome, elongate west and east, with approximately 150 feet of closure.

The second map (Fig. 7) shows the 25-foot contours on top of the Third *Marginulina* sand at an average depth of 7,800 feet, and the third map (Fig. 8) gives the 25-foot contours on top of the Ortego (producing) sand (or Fourth *Marginulina* sand) at an average depth of 8,300 feet. The outlines of the dome at these levels are very much the same as shown on the first map except that the structure becomes somewhat more pronounced with increasing depth. However, the

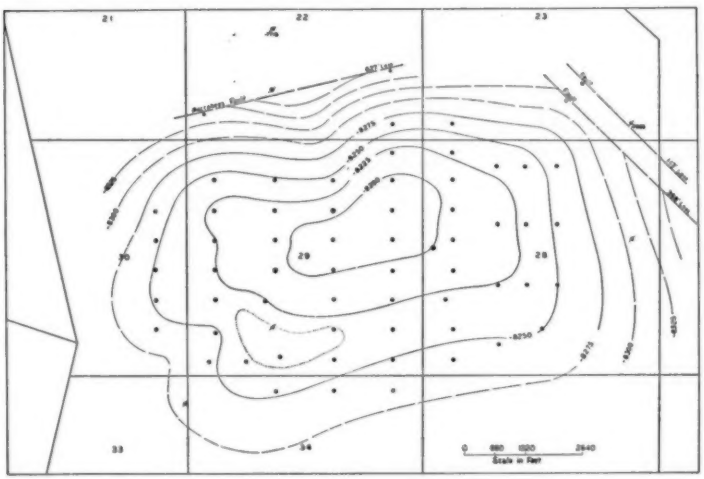

FIG. 8.—Structural map of Tepetate drawn on Ortego (Fourth *Marginulina*) sand. Contour interval, 25 feet.

closure on top of the Ortego sand does not seem to exceed 300 feet—an increase of about 150 feet. The south flank of the dome is considerably flatter than the north flank, and a pronounced nose appears in the southwest part of the field at the lower levels (Fig. 8).

No contour maps were prepared on shallower horizons within the Fleming series, as there is but little expression of structural relief observed within this formation. Also, there are no accurate and reliable markers present in this section which could be used for the construction of shallower contour maps.

The structural features are also shown on a north-south cross section through the center of the field drawn on the same horizontal

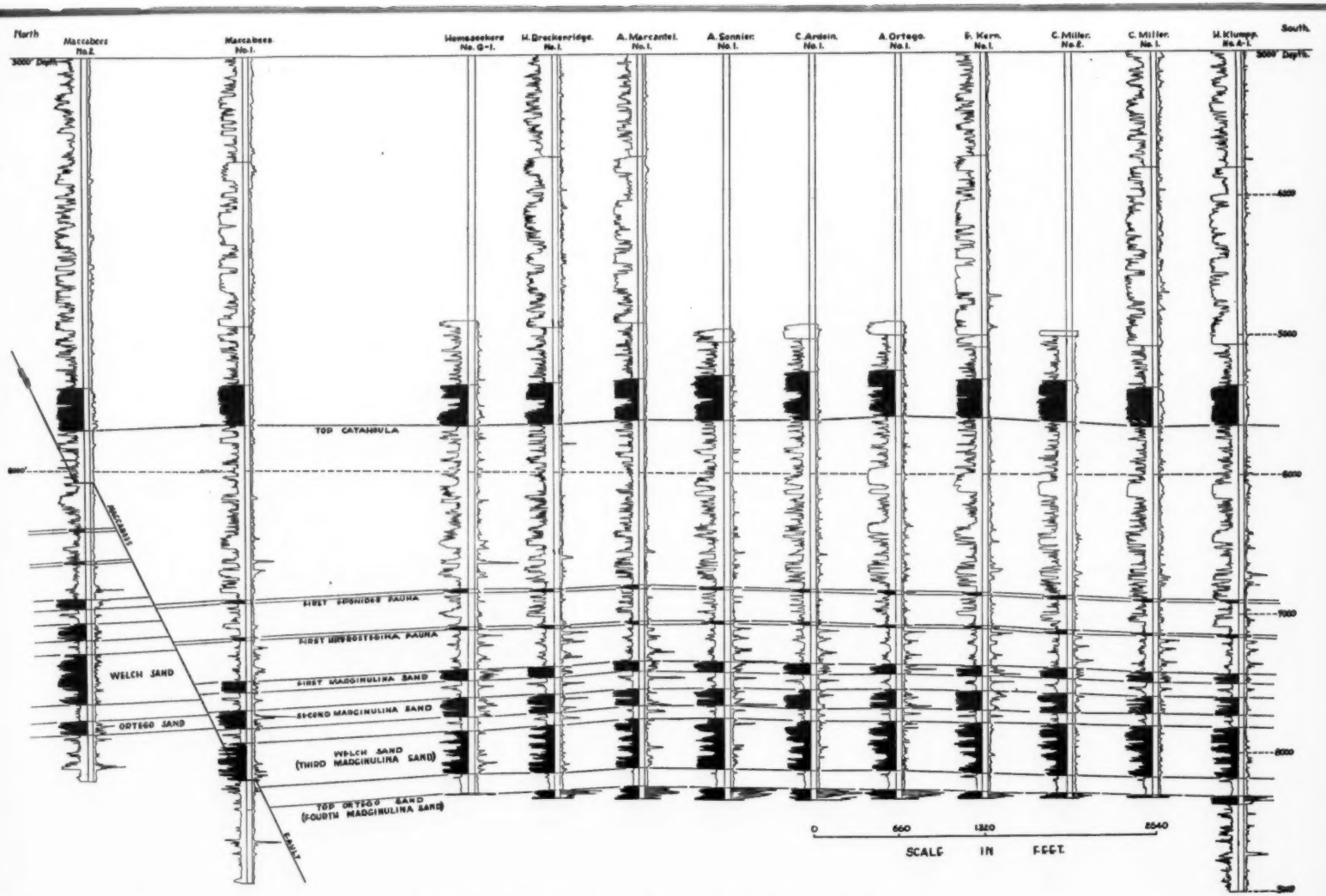

FIG. 9.—North-south cross section of Tepetate drawn from electrical logs.

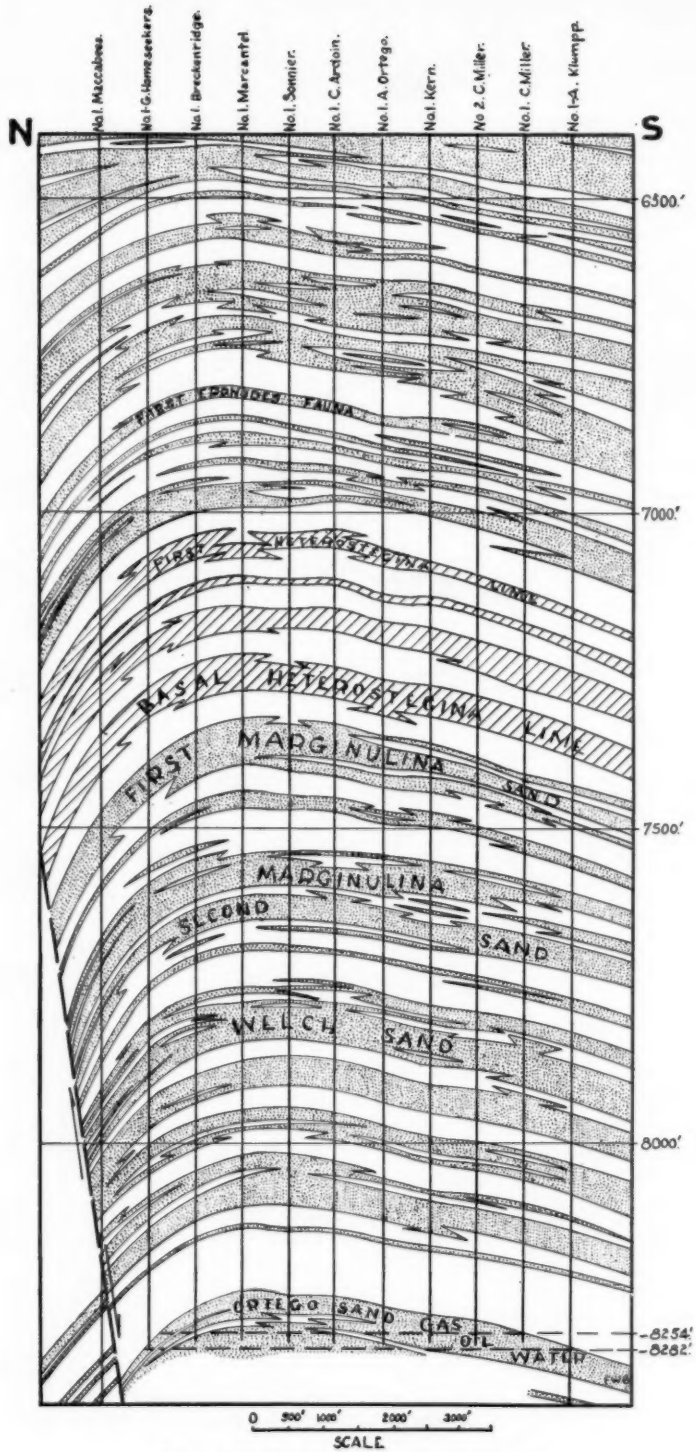

FIG. 10.—North-south cross section of Tepetate.

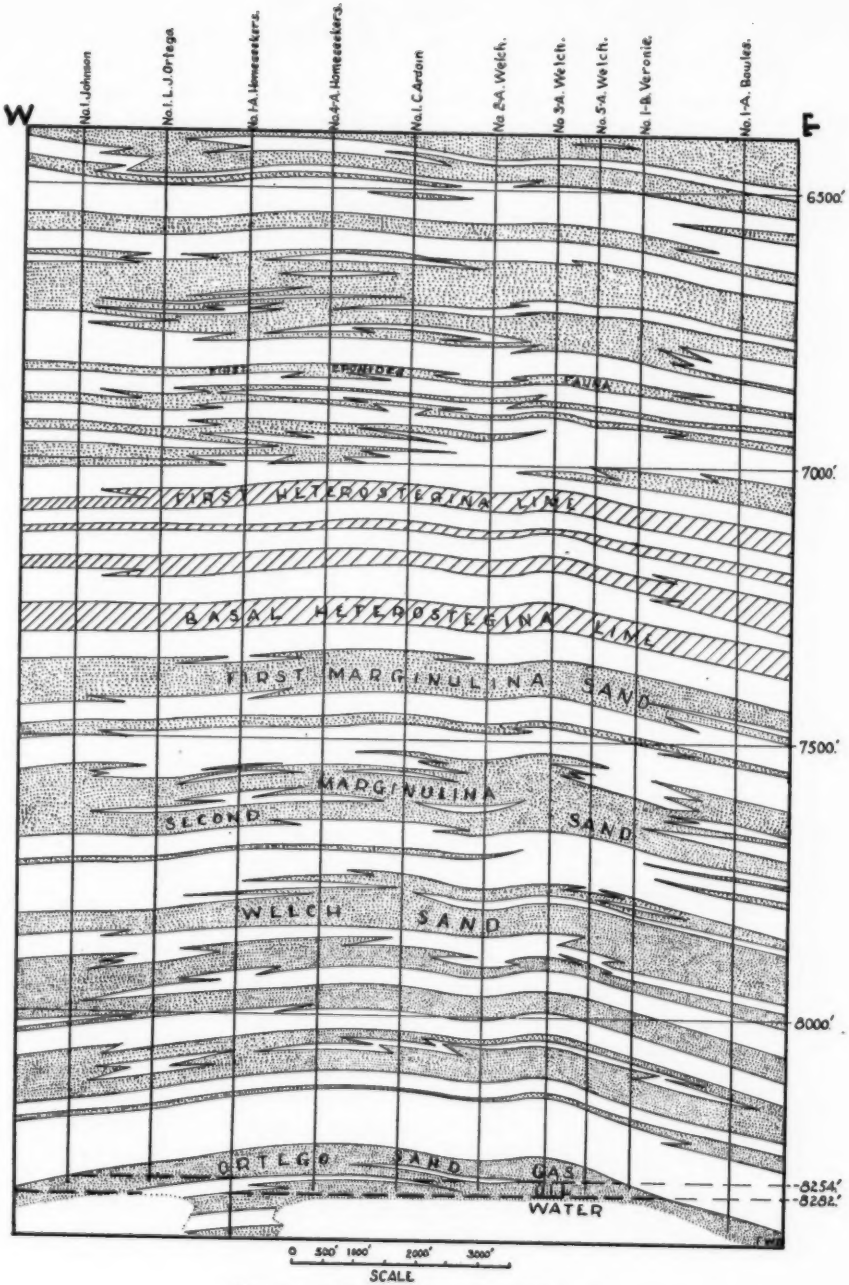

FIG. 11.—West-east cross section of Tepetate.

and vertical scale and correlated by use of electrical logs (Fig. 9). A stratigraphic interpretation of this cross section, in a slightly exaggerated vertical scale to show the increased north dip, is shown in Figure 10. A cross section prepared in the same way shows the stratigraphic and structural conditions west and east (Fig. 11).

No major faulting has been found within the productive limits of the field. This is a unique feature because the productive area is considerably faulted on most of the deep-seated structures in the Gulf Coast. A fault with about 600 feet displacement, however, was found north of the field. This fault was encountered in Maccabees No. 1 at about 8,200 feet and in Maccabees No. 2 at about 6,100 feet. Although these two points alone do not permit the determination of the exact strike and rate of dip of the fault, they definitely prove that the fault plane dips south at an angle of at least 50°, and the upthrown side is on the north. Faulting was also established in Bowles No. B-1, drilled by Loffland Brothers. As in the aforementioned case, the upthrown sides are evidently away from the field. The writers believe that these faults, or at least the Maccabees fault, are closely connected with the formation of the Tepetate structure and probably represent a younger phase of the structural history of this dome. If this is true, the Tepetate structure, naturally, is considerably larger than is outlined by the productive area and will also include the area of the upthrown, structurally high sides of the faults. In addition to these major faults, minor irregularities in thickness of section have been noticed in zones approximately radial to the productive area and possibly indicate a pattern of minor faults of 10–15 feet displacement.

STRUCTURAL HISTORY

In order to gain some additional information regarding the structural history of the Tepetate field, particularly regarding its earlier history, an isopach map has been prepared to show the local area of thinnest sedimentation, as such an area reflects the location of older structural developments. According to this map (Fig. 12), which shows lines of equal thickness between the top of the *Eponides* zone and the top of the producing sand, the area of thinnest sedimentary section for this interval seems to be considerably south of the present structurally high area (Fig. 8), pointing to an old structural development in this southern area. As shown on the map, the center of the thinnest section appears to be in Sec. 34, T. 7 S., R. 2 W. This is further substantiated by the outcome of a recently abandoned well south of the area shown and located near the southeast corner of Sec. 34, T. 7 S., R. 2 W. In this well the interval between the *Eponides* zone and the

Ortego sand is abnormally short, and the thickening of section corresponding with that found in the north, west, and east parts of the field must take place south of this well. The isopach picture as it is revealed by the available data resembles very closely the gravimetric picture; therefore, the conclusion seems justified that there exists a close geological relation between these two representations. Evidently a structural "high" of considerable extent, the outline of which is shown by the area of thinnest sedimentary section, was formed by an early salt upthrust indicated by the pronounced gravimetric minimum in Sec. 34, T. 7 S., R. 2 W.

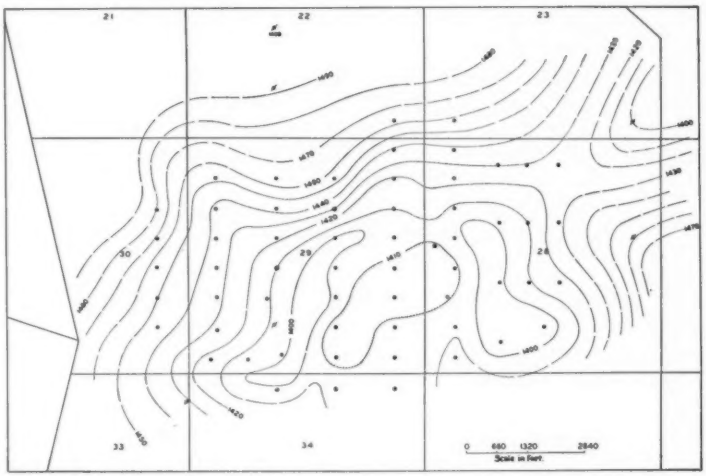

FIG. 12.—Convergence map of Tepetate drawn on interval between *Eponides* zone and Ortego (Fourth *Marginulina*) sands. Contour interval, 10 feet.

This earlier salt movement probably occurred during late Vicksburg (Oligocene) time and must have continued during all of Catahoula time, as is demonstrated by two additional isopach maps (Figs. 13, 14). These two maps show isopach contours between the tops of the Third *Marginulina* sand and the Ortego sand, and between the tops of the *Eponides* zone and the Third *Marginulina* sand, respectively. As there is evidently no material difference between these two maps, the postulated earlier salt upthrust and the deformation of the overlying beds must have continued unchanged at least through the time interval represented by the two maps.

Unfortunately, the structural development of the Tepetate field

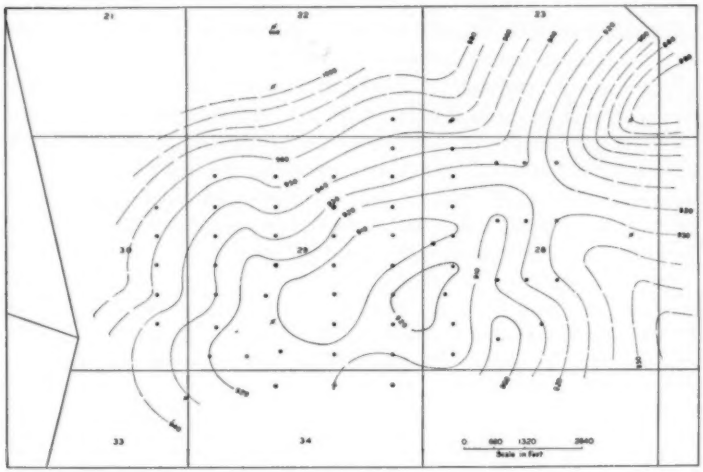

FIG. 13.—Convergence map of Tepetate, drawn on interval between *Eponides* zone and Welch (Third *Marginulina*) sands. Contour interval, 10 feet.

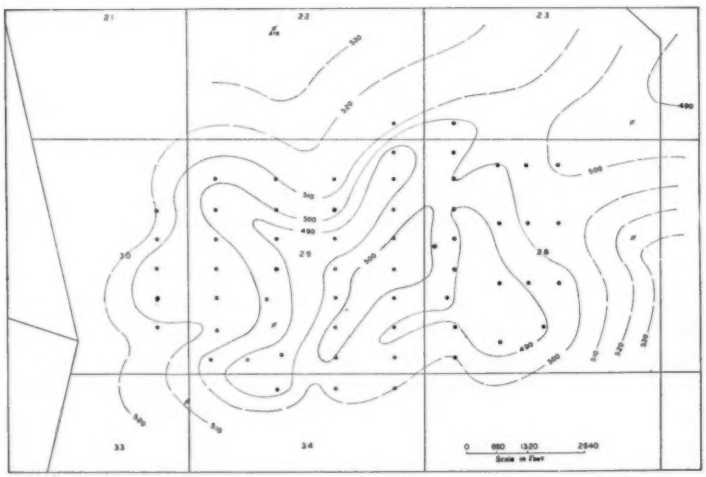

FIG. 14.—Convergence map of Tepetate, drawn on interval between Welch (Third *Marginulina*) and Ortego (Fourth *Marginulina*) sands. Contour interval, 10 feet.

can not be as accurately traced through the later periods as through Catahoula time. This is due mainly to the fact that only in the earlier wells were electrical logs made of the shallower formations; therefore, accurate isopach maps can not be prepared. From the available data it appears that during Fleming time a normal thickness of sediments was deposited over the Tepetate field. Evidently the salt movement came to a rest with the close of Catahoula time.

The tremendous faulting north of the field as evidenced by the Maccabees fault probably occurred during post-Miocene time. The magnitude of the displacement and the position of the fault plane indicate a close relation of the fault to the deep-seated salt mass, and it appears that in all probability the present structurally high area is only a slight uplift of the north flank of the older structure occurring in connection with this faulting. Therefore the formation of the present Tepetate field may be of recent age and represents only a secondary feature in the development of the Tepetate structure.

An area of thin sedimentary section is present also northeast of the field, but there are not sufficient data available at this time to indicate its significance.

PRODUCING SANDS

All the producing and potentially producing sands discovered in the Tepetate field are confined to the *Marginulina* zone. Good oil showings were encountered in the tops of the First and Third *Marginulina* (Welch) sands, and in a very thin sand (Young sand) occurring about 70 feet above the Welch sand. These sands are somewhat variable and possible future production from them will be limited in areal extent by both sand conditions and structural position.

The main producing sand of the Tepetate field is the Fourth *Marginulina* or Ortego sand. The thickness of this sand varies from 50 feet on the southern flank to more than 100 feet on the northeastern side. It is somewhat coarse-grained, mostly clean and ordinarily very soft sand, though here and there hard calcareous streaks are encountered. In the western part a prominent shale break appears, dividing the sand into an upper and a lower member. Numerous smaller shale breaks are present throughout the sand section, and there is a strong tendency, particularly in the upper part of the sand, toward a gradation westward into shaly sand and finally shale. These changes are illustrated on a diagrammatic cross section through the Ortego sand (Fig. 15).

The main producing horizon has a large gas cap of a maximum

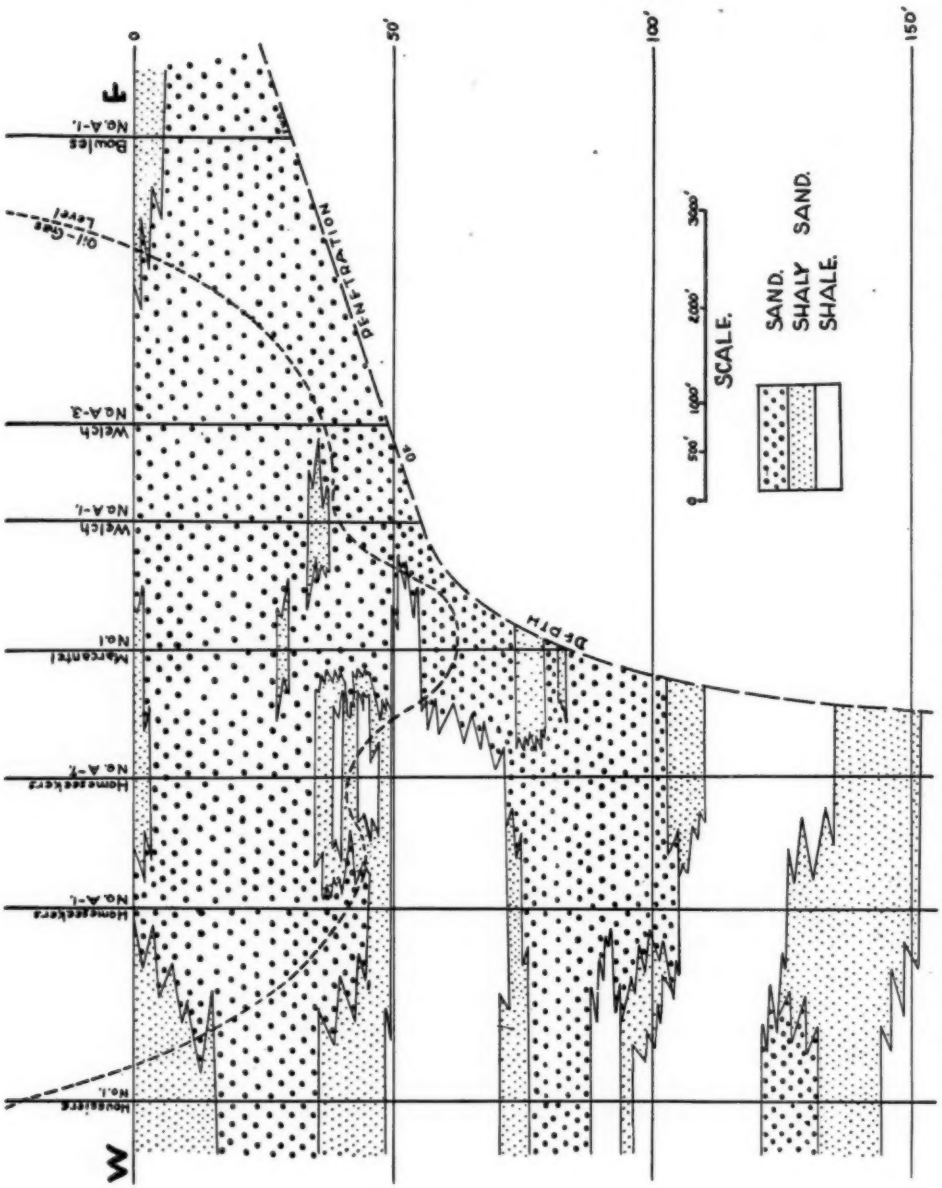

FIG. 15.—Diagrammatic cross section of Ortego (Fourth *Marginulina*) sand, drawn with top of sand as datum.

thickness of 60 feet. The oil-gas contact is reached at 8,255 feet below sea-level and the water level at 8,282 feet below sea-level, salt water evidently underlying the entire field. The oil zone, therefore, is about 28 feet thick.

The large gas cap and the bottom water makes it a somewhat difficult task to complete an oil well entirely successfully in the field. In order to avoid a high gas-oil ratio, it was found necessary to complete a well at least 10 feet below the oil-gas contact. It is also advisable to complete a well at least 10 feet above the water level in order to avoid an early water intrusion. This leaves a narrow margin of about 8–10 feet for successful completion. Unfortunately, in some places, this particular completion margin consists partly or entirely of shale and the result is a high-ratio oil well or merely a gas well.

About 200 feet below the Ortego sand there occurs a last productive sand which, however, has been found to contain only gas.

CONCLUSION

The writers have attempted to present in this paper the salient stratigraphic and structural features of the Tepetate field. Although several important problems, particularly concerning the stratigraphy, still remain unsolved, they feel confident that with the presentation of the gravimetric, reflection-seismograph, structural, and isopach maps this paper should prove to be of considerable interest to the petroleum geologist engaged in geological work in the Louisiana Gulf Coast.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 22, NO. 3 (MARCH, 1938), PP. 306-314

GEOLOGICAL NOTES

BIGHORN BASIN-YELLOWSTONE VALLEY STRUCTURAL FIELD CONFERENCE, 1937[1]

W. T. THOM, JR.[2]
Princeton, New Jersey

C. W. Tomlinson has courteously forwarded to me a 57-page manuscript composed of his notes and discussions resulting from last summer's structural field conference in the Yellowstone-Bighorn region, and he also writes me that he has used this manuscript material as the basis for lectures before several of the Mid-Continent geological societies. Many others have therefore heard his ideas and interpretations—which I find particularly interesting, not only because of the questions he has raised and the suggestions he has offered, but also because of the direct indications his paper gives as to the uses and limitations of the field conference method when applied to the research phase of structural geology (as compared with stratigraphic research).

The Yellowstone-Bighorn Conference, as planned, had as its multiple objectives (1) the "demonstration" of typical structural features of the region to all interested visitors; (2) the test-by-trial of the optimum number of participants to be included in such other structural conferences as might be conducted for purely research purposes; (3) the length of time that should be allowed for a review as comprehensive as that undertaken; (4) what (in this particular instance) the response would be on the validity of the ramp uplift postulate; and (5) what questions and suggestions would arise from the Conference;—especially inasmuch as Professors Bucher, Chamberlin, and I are now preparing a comprehensive report summarizing the structural results of our group's work in the region during the past eight years.

The groups sponsoring the Conference also naturally wished to make use of the opportunity to return in some measure the courtesies which many of their members have enjoyed in previous years as participants in other field conferences, especially those sponsored by the Kansas Geological Society.

[1] Manuscript received, February 7, 1938.

[2] Department of Geology, Princeton University.

Because of lack of present (and of near-future) opportunity to compare my conclusions with those of my collaborators in the recent undertaking, the opinions given here are merely one individual's—but, even so, they may be of some interest, especially when taking Dr. Tomlinson's discussion as a context. These conclusions of mine, for what they may be worth, can be summarized as follows.

Use of field conference method in structural research.—The results of the Yellowstone-Bighorn Conference amply re-demonstrated that it is only by conference, *at the outcrop*, that structural disagreements can be cleared up, and (in my opinion at least) they further proved that from the point of view of *maximum efficiency*, scientific and mechanical, an enrollment of about 25 to 30 participants would provide adequate checking of observations and interpretations, while maintaining high flexibility of operation. Moreover—from the *research* aspect of the case, as contrasted with the "*demonstration*" point of view—my opinion is that at least 2 weeks in the field would be required to answer Dr. Tomlinson's questions, and to let all entertaining similar opinions satisfy themselves as to what conclusions would be correct with reference to the theme-problem of last summer's conference.

Validity of the ramp hypothesis.—I imagine that a number of conference members besides Dr. Tomlinson felt that normal faulting (rather than ramp uplift) was either possibly or more probably responsible for the upturned monoclines which they saw during the conference trip. It still remains possible that this is the correct conclusion, though (personally) after proceeding on that expectation for several years I have been forced to abandon it by accumulating field evidence. This evidence, which was partly outlined in the Conference *Guidebook*, and which will be fully set forth in the joint report (which Professors Bucher, Chamberlin, and I are preparing) is too voluminous to be contained in a letter.

This extensive report may add enough evidence to clear the problem to the satisfaction of some, but with others a thorough testing, at the outcrop, of both evidence and conclusion will probably be required in order that they may feel that they are dealing with actual conditions and not theory, insofar as the ramp interpretation is concerned. For any who are thus interested, we shall be glad to arrange for group reviews from time to time, if and as desired and as may prove possible. In this connection it may be of interest to some to note that the procedure on such "check conferences" (which our Red Lodge members feel we have used successfully in our own structural activities) has consisted of the following steps.

1. Individual examination of all pertinent outcrops.

2. Comparison of findings. If all observers are in agreement, then the observations made are regarded as correct.

3. After an agreement on observations has been reached, individual interpretations of the significance of the field evidence are presented. If all observations *and* interpretations agree, the case is considered closed, and the resulting conclusion is regarded as a fact.

4. If the interpretations are not harmonious the points of evidence which would be decisive as between the views presented are discussed and the outcrops are again combed. If decisive evidence, limiting interpretations to one, is obtained, the case is regarded as proved and closed. Otherwise the alternative choices of interpretation are recorded, and the study is transferred to other features of like character, where, perhaps, the evidence needed for a final decision may be discoverable.

On behalf of the groups which sponsored and carried out the Conference, I wish to thank the many guests who participated in it, for their interested and sympathetic coöperation in the conduct of the trip. I also hope that any of its participants, who have other questions, criticisms, or suggestions with regard to the Conference, will assist by forwarding these for inclusion in the Conference records.

C. W. TOMLINSON, Ardmore, Oklahoma (discussion received, February 14, 1938):

The manuscript mentioned by Dr. Thom was submitted to him in compliance with his request for comment from the guests at last summer's Bighorn-Yellowstone tectonics field conference, ably led by him. His reference to the text of the manuscript makes desirable a word of explanation.

To explain some of the asymmetric anticlines of that region, Bucher, Chamberlin, and Thom[1] have offered (cf. this *Bulletin* for June, 1933) an hypothesis of upward "trap-door" rotation of rigid granitic blocks of large dimensions.

In later publications by some of their associates, and in the conference guide book, faults of this type have been sketched under most of the asymmetric anticlines illustrated. Many of them have been sketched as curved ramp thrust planes which possess low dip at depth, but steeper upward. One of the major theses presented in the guidebook is that even the superficially unfaulted asymmetric anticlines are surface expressions of subsurface faults. However, in recent letters both Dr. Chamberlin and Dr. Bucher state that they do not believe the ramp hypothesis to be so generally applicable, nor do they believe that faulting must be associated with all of the asymmetric anticlines in question.

The alternative hypothesis offered in the manuscript mentioned is re-

[1] W. H. Bucher, R. T. Chamberlin, and W. T. Thom, Jr., "Results of Structural Research Work in Beartooth-Bighorn Region, Montana and Wyoming," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 6 (June, 1933), pp. 680–93.

ferred to by Dr. Thom as "normal faulting." Rather, it is simple compressional folding. This may result in great vertical differential uplift. On the steeper sides of some of the higher folds such uplift has produced, and has in turn been facilitated by, strike faulting. In many cases these strike faults, at their surface traces, are very steep, like the folded sediments alongside. They may have either normal or reverse hade. Definite overthrusting has occurred along some of them, with lateral bulging of the adjacent uplift.

The essential difference between the two hypotheses in question is not the difference between reverse and normal faulting, for both are undeniably present. It is the difference between rotational ramp thrusting and ordinary compressional folding with accessory faulting. The former requires the presence of ramp faults beneath superficially unfaulted anticlines. The other does not.

The main point of my comment is that the matter is still hypothetical. The field evidence which has been shown or described to date does not warrant promotion of the ramp idea above the rank of hypothesis.

The most serious limitation of a structural field conference is its inability to see underground. In but few instances can there be well-founded difference of opinion as to what was seen on an outcrop by last summer's conference. Unfortunately, even in those cases it is not likely that entire agreement on the visible facts would be sufficient to complete the proof for either hypothesis as to deep-seated structure and the mechanism of uplift.

In no case is there question of the excellence of the detailed mapping of areal geology by Dr. Thom and his colleagues. By enthusiastic and painstaking labor in many types of geologic inquiry, they are compiling a truly great symposium on the geology of their chosen region.

CORRELATION OF COCKFIELD AND GOSPORT FORMATIONS, EASTERN MISSISSIPPI AND WESTERN ALABAMA[1]

B. W. BLANPIED[2] AND ROY T. HAZZARD[2]
Shreveport, Louisiana

The Gosport formation of the Upper Claiborne of Alabama was first correlated with the Cockfield formation by Vaughan.[3] He believed the Cocksfield Ferry beds of Louisiana to be "equivalent in a general way to the Claiborne sands[4] of Alabama. Harris[5] reaffirmed

[1] Manuscript received, February, 1938.

[2] Gulf Refining Company.

[3] T. Wayland Vaughan, "The Stratigraphy of Northwestern Louisiana," *Amer. Geol.*, No. 15 (1895), pp. 209 and 220.

[4] The Claiborne sands of Alabama, in Vaughan's report and the upper Claiborne of east Mississippi and Alabama, of Harris' report refer to the Claiborne Fossiliferous sands or Gosport sands.

[5] G. D. Harris, "The Tertiary Geology of the Mississippi Embayment with Special Reference to the State of Louisiana," *A Rept. on the Geology of Louisiana, Special Repts.* No. 1 (1902), p. 21.

the correlation of the "Cocksfield Ferry beds" with the upper Claiborne of east Mississippi and Alabama. He referred to the beds as "Cockfield Beds." Very little has been written regarding the physical relationship of these two lithological units.

It is the writer's opinion that the lithological change from the marine Gosport sands of Southwestern Alabama to the non-marine Cockfield of eastern Mississippi represents a lateral and gradational interfingering of marine fossiliferous green sands with lacustrine, non-fossiliferous sands and carbonaceous clays. The classic outcrops at Claiborne Bluff, on the Alabama River, in which the Gosport fossiliferous sand is typically exposed, affords an excellent example of interfingering of lignitic clays within the fossiliferous green sand of the Gosport. The following description is by Smith.[6]

> Ferruginous sand, holding vast numbers of comminuted in addition to well preserved shells. Near the center of this there are in places, thin bands of lignite, and along the ferry road the upper part of it is composed of laminated gray clays filled with leaf impressions. This is the source of the celebrated Claiborne fossils, and we shall call it the Claiborne Fossiliferous Sand. . . . Thickness about 15 to 17 feet.

The beds underlying this Gosport section were described as glauconitic, sandy marl with *Ostrea sellaeformis*, which beds are now assigned to the Lisbon formation. The Claiborne Fossiliferous Sand was given the name of Gosport greensand by Smith,[7] since this fossiliferous sand is well exposed at Gosport landing on the Alabama River, a few miles below Claiborne Bluff. Berry[8] in referring to the Gosport sands at Claiborne Bluff states:

> Near the contact of the Claiborne with the Jackson, the glauconitic sands of the Gosport contain a small lens of laminated gray clay that carries an abundance of fossil plants. These plants are for the most part well preserved but difficult to collect because of the jointing of the clay. The 15 species, over half of which are common to the Yegua (Cockfield) have been determined from this locality.

In 1919, Harris[9] divided the Claiborne Group of the Gulf region into two stages, as follows.

Claiborne Stage, lignitic or lacustrine (so-called Claiborne)
St. Maurice Stage, Marine (so-called Lower Claiborne of our various previous contributions)

[6] E. A. Smith, *Geol. Survey of Alabama, Geology of Coastal Plain* (1894), p. 129.

[7] *Geol. Survey of Alabama, Underground Water Resources of Alabama* (1907).

[8] E. W. Berry, "The Middle and Upper Eocene Floras of Southeastern North America," *U. S. Prof. Paper 92* (1924), p. 10.

[9] G. D. Harris, "Pelecypoda of the St. Maurice and Claiborne Stages," *Amer. Paleon.*, Vol. 6 (1919), pp. 5–7.

He is quoted as follows.

The more we study the so-called Claiborne and Lower Claiborne faunas the more distinct do they appear. The Lower Claiborne or St. Maurice represents an age of general depression along the Gulf border with widely distributed molluscan remains; the Claiborne (stage), a somewhat uplifted lacustrine condition with rarely local depressions sufficient to allow of the incursion of the warm seas from the south with their teeming marine life. One notable example of this kind is to be seen at the famous bluff on the Alabama, though in the roadside scarcely a mile above, the "sands" give way largely to lignite deposits.

West of Claiborne Bluff, in outcrops along Bassett's Creek, in the SE. ¼, NE. ¼ of Section 11, T. 6 N., R 2 E., and in SE. ¼, NE. ¼ of Section 26, T. 6 N., R. 2 E., reddish brown sand, orange sand and gray clays are found directly underlying Moody's marl and above Gosport fossiliferous sands. Moody states:[10]

The Jackson marls lie directly on the Gosport sand at the type Claiborne locality, but a few miles farther west the lignitic Cockfield formation is found between the two. In central Mississippi the Gosport-Lisbon formation of Alabama has expanded into three well individualized formations which have received names as follows: Wautubbee marl at the top, and Winona sand at the base, with the non-marine Kosciusko sand in the intermediate position. With the Cockfield formation at the top of the Claiborne group and the Tallahatta at the base, the Mississippi Claiborne is divided into five formations with an aggregate thickness of 1,500 feet.

Moody referred to the Gosport-Lisbon as one formation in Alabama, and correlated it with the Wautubbee formation of Mississippi. At the type locality of the Lisbon formations and at Claiborne Bluff, the Lisbon contains abundant *Ostrea sellaeformis* species. The Wautubbee marl of Mississippi is also characterized by *Ostrea sellaeformis*. Smith repeatedly refers to the Lisbon formation as the *Ostrea sellaeformis* beds. The writer has never seen this oyster in the Gosport sands and can not find any record of it having been found in the Gosport formation. Harris[11] states that the type locality of the *Ostrea sellaeformis* (typical) is from the lower calcareous layers, Claiborne Bluff, Alabama.

In the NW. ¼, NW. ¼ of Section 28, T. 7 N., R. 2 E., in Clarke County, an excellent section may be seen in the banks of a small creek in which the basal "Scutella bed" of the Moody's marl directly overlies fossiliferous coarse sand of the Gosport, with blue clay of the Lisbon formation lying below the Gosport. Another similar exposure

[10] C. L. Moody, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 5 (May, 1931), p. 541.

[11] G. D. Harris, *Amer. Paleon.*, Vol. 6 (1919), pp. 11–12.

was found in NW. ¼, NE. ¼ of Section 17, T. 7 N., R. 2 E., with Moody's marl overlying fossiliferous Gosport sands. Here the Gosport contained large grains of glauconite.

The Gosport sands have not been found in outcrops west of the Alabama state line. So far as known, they are confined to the following counties of Alabama: Monroe, Clarke, Washington, and Choctaw. One of the most westerly outcrops of the Gosport was described by Cooke[12] at Willow Branch, Section 14 or 15, T. 9 N., R. 4 W., Choctaw County. Following is Gosport sand section described by Cooke.

	Feet
Reddish-brown, ferruginous, glauconitic sand containing casts of mollusks with a 1 foot shell bed at bottom	7
Dark gray to black sandy clay with shells	3½
Laminated, gray sand and clay with fossil leaves	7
Dark-green to black glauconitic sand loaded with Claiborne shells	2
Dark green to black, somewhat sandy clay; weathers with fissile parting resembling "coal blossom"	5
Reddish-brown ferruginous sand to stream bed (1 or 2 feet concealed at bottom)	10

The interbedding of Gosport fossiliferous sands with lacustrine Cockfield type beds is well shown in the above section. In the SE. ¼ of Section 15, T. 10 N., R. 5 W., an exposure showing Gosport fossiliferous sand underlying the Moody's marl, with dark sandy clay below the Gosport has been noted. This locality is about ¼ mile from the Mississippi-Alabama state line. Another good section showing the fossiliferous Gosport sand underlying the Moody's marl may be seen on the Melvin-Gilbertown road in SE. ¼ of Section 28, T. 11 N., R. 4 W., about 0.4 mile east of Push Cush Creek in Choctaw County. The Gosport is about 15 feet thick, with lignitic clay underlying. In Sec. 3, T. 11 N., R. 4 W., and Sec. 18, T. 11 N., R. 3 W., exposures of the Moody's marl with underlying lacustrine-type Cockfield sands and lignitic clays may be seen, with the fossiliferous Gosport sands not present.

Across the state line, in Clarke County, Mississippi, the fossiliferous Gosport sands have never been found by close reconnaissance mapping. The contact of the Moody's marl with the lacustrine type Cockfield has been mapped from the state line, northwestward to the vicinity of Jackson and Yazoo City in Mississippi. An interesting section is exposed in Garland Creek in southern Clarke County, in Sec. 28, T. 1 N., R. 16 E., in the South Bluff of the creek. The following section is described.[13]

[12] C. W. Cooke, *Geol. Survey of Alabama, Special Report 14* (1926), pp. 272–73.

[13] *Guidebook for the Shreveport Geological Society's 11th Annual Field Trip* (1934), p. 32.

		Feet
Yazoo Clay (Jackson)	Greenish and gray, blocky calcareous fossiliferous clay...	10
Moody's Marl (Jackson).....	Fossiliferous marly limestone.....	1
	Greenish gray glauconitic sandy marl.....	8
	Six to twelve inches of fossiliferous glauconitic marl with irregularly distributed black shale fragments in the marl..	1
"Transition Zone" (Jackson).....	Black carbonaceous well bedded shale with thin partings of fossiliferous marl.....	2
	Massive lignitic sands and clays with pockets of fossiliferous glauconitic marl.....	8
Cockfield.....	Interbedded chocolate colored shales and lignitic sands, to creek bed.....	6

The "Transition Zone," which is Jackson in age according to foraminiferal assemblage, has been mapped in detail in the vicnity of Quitman, in Clarke County, and was found to overlie lignitic sands and clays of the Cockfield. From core drilling in the vicinity of Quitman, the Cockfield was found to have a thickness of 75 feet, which thickness indicates a rapid thickening westward from Claiborne Bluff, where it is represented by thin clay lenses in the Gosport.

The following tabulation of data obtained from core-drill samples, cores, and cuttings, shows the writer's interpretation of the thicknesses of zones penetrated in the vicinity of the Jackson fault and the south flank of the Hatchetigbee anticline in Alabama.

Well and Location	*Thickness in Feet of Transition Zone*	*Thickness in Feet of Gosport*	*Thickness in Feet of Typical Cockfield Penetrated below the Gosport*
Gulf-Clements No. 1 Sec. 23-6 N.-2 E. Clark Co., Ala.	0	30	24
Gulf-Boseman No. 1 Sec. 25-7 N.-1 W. Washington Co., Ala.	20	30	44
Gulf-Wilson No. 1 Sec. 28-7 N.-1 W. Washington Co., Ala.	16	24	42
Gulf-Thompson No. 1 Sec. 39-8 N.-2 W. Washington Co., Ala.	16	24	20
Gulf-White No. 1 Sec. 12-8 N.-3 W. Washington Co., Ala.	10	24	20
Arkansas-Jordan No. 4 Sec. 31-6 N.-2 W. Washington Co., Ala.	17	40	5
Arkansas No. 26 Sec. 5-5 N.-2 W. Washington Co., Ala.	17	37	40

Cores from the basal part of the Gosport sands in the Arkansas-Jordan No. 4 showed an interbedding of fossiliferous green sand and gray and brown clays. Only 5 feet of carbonaceous sands and clays were penetrated at the total depth of this core-drill test. As noted from the accompanying tabulation, the "Transition Zone" is thought to be present in all of the core-drill tests west of the Tombigbee River in Washington County. The Gosport is well developed and the underlying lacustrine Cockfield type sands and clays are becoming quite prominent in the section in all of the core tests here listed.

Lowe[14] in describing his Wautubbee marls states:

> The Wautubbee marls constitute the most extensive division of the Lisbon. . . . The Wautubbee beds are all marine consisting of highly calcareous and fossiliferous marls, of gray to almost white color, or of darker bluish and greenish tints, due to the presence of glauconite. In the vicinity of Newton and a few other localities these marls pass vertically into clays or sands which are often lignitic and fossiliferous.
>
> The Wautubbee marls are locally rich in marine fossils, exhibiting a very characteristic fauna. The large saddle-shaped oyster, *Ostrea sellaeformis* is especially abundant. . . . In the uppermost part of the Lisbon the marls give place to lignitic clays, sands and lignites. This phase of the formation is sufficiently persistent to justify its consideration as a distinct member under the name of the Cockfield.

In summary, it may be seen that lenses of lacustrine, carbonaceous clays bearing fossil leaves are present in the Gosport sands at Claiborne Bluff; also in surface exposures westward of Claiborne Bluff, Cockfield type sands and clays are found above the Gosport sands as well as interbedded within them. From core-drill data the Cockfield type sands and clays are found below the Gosport, which relationship has been seen in several of the surface outcrops mentioned above. In the vicinity of Quitman, Clarke County, Mississippi, the Cockfield sands and clays occupy a stratigraphic position between the "Transition Zone" of Jackson age and the top of the fossiliferous Wautubbee marl; the same stratigraphic interval is represented in western Alabama by the sediments between the base of the Moody marl of Jackson age and the top of the Lisbon formation (top of the *Ostrea sellaeformis* zone). This stratigraphic relationship has been found both in surface outcrops and in core tests. As mentioned, no fossiliferous Gosport sand has been found on the surface or in core tests in the Quitman area.

[14] E. N. Lowe, "Geology and Mineral Resources of Mississippi," *Mississippi State Geol. Survey* (1925), pp. 69–70.

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to members and associates.

MARINE PALEOCENE AND EOCENE OF NORTH GERMANY AND SOUTH SCANDINAVIA, BY THEODOR MÜLLER[1]

REVIEW BY RALPH D. REED[2]
Los Angeles, California

Das marine Paläozän und Eozän in Norddeutschland und Südskandinavien, mit einer Zusammenstellung der gesamten Literatur (Marine Paleocene and Eocene of North Germany and South Scandinavia, with an exhaustive bibliography). By THEODOR MÜLLER. Gebrüder Borntraeger (Berlin, 1937). 120 pages, a paleogeographic map, bibliography of 393 titles; bound in tough paper. Price, RM5.

The proper correlation of the Midway, the Martinez, and other transitional Mesozoic-Tertiary formations of the United States is puzzling. One great source of difficulty has long been uncertainty as to the exact conditions in the type areas of the standard stages and formations that represent this part of geologic time. The Danian and Montian stages, named for exposures in Denmark and in Belgium, are generally taken, respectively, as uppermost Cretaceous and lowest Paleocene. The Danian has been hard to find in Belgium, the Montian difficult to identify in Denmark; and no generally satisfactory reason has been advanced for referring either of them definitely to either Mesozoic or Tertiary. The Belgian geologic map of 1900 calls the Montian Paleocene, and the 1929 edition calls it Cretaceous. In the second edition (1936) of Gignoux's *Géologie Stratigraphique*, the Danian is considered uppermost Cretaceous, a deposit of the center of the Cretaceous North Sea, and is supposed to lie conformably on the Maestrichtian. In the sixth and seventh (1924) edition of Kayser's *Lehrbuch*, on the other hand, the Danian is placed at the base of the Tertiary. Kossmat (*Paläogeographie und Tektonik* (1936), p. 209) agrees with Gignoux.

Dr. Müller's volume deals largely with the data and conclusions of his predecessors among the Scandinavian and North German geologists who have busied themselves with local stratigraphic problems. Stolley, Voigt, Ravn, von Koenen, Grönwall, Ødum, Rosenkrantz, and Bøggild are among those frequently mentioned. It is somewhat hard to tell how much personal study of exposures, rock samples, and fossils the author has made, but there is no reason to question the completeness of his knowledge of the results of studies made by other people. Certainly the reviewer has seen nothing that even approaches the present volume in respect to the completeness and lucidity with which it presents the data bearing upon this subject.

[1] Manuscript received, February 3, 1938.

[2] The Texas Company.

A reading of the volume reveals many and excellent reasons for the uncertainties mentioned in the opening paragraph of this review. In the first place, the fauna of the Danian is clearly transitional; that is, it is not definitely either Cretaceous or Tertiary. It lacks ammonites, belemnites, and *Inoceramus*, but contains echinoids and mollusks "of Cretaceous aspect." In the second place, most of the formation contacts in question have been described as conformable by some observers and as unconformable by others; no single contact is so definitely and persistently unconformable as to make an obvious boundary. In the next place, many of the best and most fossiliferous exposures of the rocks in question are transported masses, enclosed in glacial drift and violently disturbed in structure. The most widespread Danish Paleocene formation may be examined in place in just two outcrops. No formation seems to be exposed so continuously as to make readily determinable its changes in thickness from place to place or its relations to overlying and underlying formations. Only as a result of deep drilling in recent years, in fact, have many important relations been determined at all and some of them are still uncertain. To make matters still worse, one very important Lower Tertiary formation of Denmark is almost completely unfossiliferous, and others have unfossiliferous facies.

With these sources of trouble well in mind, the reader readily forgives the mistakes of the past and uncertainties of the present, and freely admires the great accomplishments of Scandinavian and North German geologists, as summarized by Dr. Müller. Among the more interesting facts and conclusions, not all of which are presented as absolutely certain, the following may deserve mention.

The Danian of Denmark, though clearly transitional, should be kept in the Cretaceous, since the evidence cited in favor of its Tertiary age is too vague to justify a major change in stratigraphic classification. This sounds a little like saying that the chief reason for calling the Danian Cretaceous is because it is customary to do so but Dr. Müller seems to feel that there are other good reasons, too.

A coal shaft in Belgium has revealed Danian lying upon Maestrichtian, and showed, furthermore, that Danian fossils occur in a formation that had previously been classed as Montian. Danian and Montian are thus in part correlative, but Müller adopts the view that they are not completely so. He puts the "tuffeau de Ciply" in the Danian and the "calcaire de Mons" in the Paleocene; and correlates with the latter the Danish Lower Paleocene "glauconitic limestone of Lellinge" and "glauconitic marl of Copenhagen." As Middle Paleocene (Thanetian) he classes the "gray noncalcareous clays" and "Kerteminde marls" of Denmark, and as Upper Paleocene (Sparnacian) the widespread "Moler" and other clays with intercalated ash beds in Denmark and North Germany. There is an interesting discussion of the source of the ash, another subject upon which differences of opinion persist.

A highly unfossiliferous plastic clay represents Lower and Middle Eocene (Ypresian and Lutetian); and some siliceous rocks, absent in Denmark but present locally in North Germany, represent the Upper Eocene.

Some of the interesting paleogeographic conclusions that are scattered through the text are summarized at the end in a paleogeographic map. With it is a second map, showing the somewhat divergent views published by von Linstow in 1922.

Concluding reflections, not to be interpreted as reflecting adversely upon Dr. Müller's book, are as follows.

How much simpler the science of stratigraphy would be if Chance, or the Principle of Priority, or Hard Luck, or possibly just Human Perverseness had not decreed that most type localities should lie in regions with poor exposures or practically none. It seems very likely that the complete sequence of Late Cretaceous-Early Tertiary geologic events and faunas will be clarified in many localities other than the type localities, long before it is understood in Denmark and North Germany; and this despite the valiant and altogether admirable efforts lavished by Danish and North German geologists upon their unsolvable problems. Would the progress of stratigraphic geology be accelerated if the adoration of type localities were supplanted in geologists' minds by a devout seeking for good localities?

Whatever the answer to such questions may be, it is worth noting in conclusion, that the region of Denmark and North Germany is another in which stratigraphers are under great obligations to drillers. Well sections, says Dr. Müller, have in recent years furnished a sequence of formations that differs notably from that adopted earlier on the basis of a study of scattered outcrops.

METHODS IN PALEONTOLOGY
BY CHARLES L. CAMP AND G. DALLAS HANNA[1]

REVIEW BY RALPH D. REED[2]
Los Angeles, California

Methods in Paleontology. By Charles L. Camp and G. Dallas Hanna. University of California Press, Berkeley (1937). A 14-page introduction, 153 pages of text, frontispiece, 56 text figures, list of 195 references, and an index. 5.5×8.75 inches. Cloth. Price, $2.50.

This little manual of methods in paleontology has two authors, each of whom would be well qualified to write a much larger volume on the same subject. Charles L. Camp teaches vertebrate paleontology and directs the paleontological museum at the University of California. G. Dallas Hanna is curator of invertebrate paleontology at the California Academy of Sciences and chief paleontologist for the Associated Oil Company.

The introduction to the manual, written by Professor Camp, discusses the nature of fossils, tells where and how they are found, and mentions some of the men who have pioneered in the business of fossil-hunting and collecting.

Part I, also by Professor Camp, deals with methods used in vertebrate paleontology. It is divided into two sections, entitled respectively "Field Methods" and "Laboratory Methods."

The discussion of field methods, though intended for the use of people ambitious to collect fossil vertebrates, is interesting reading for those of us who prefer not to do the collecting ourselves. In the first place, the discussion makes it clear that modern collecting is a specialized art, in which most of us

[1] Manuscript received, February 14, 1938.

[2] The Texas Company.

could only become bunglers, to the detriment of science and to the dismay of professionals. In the second place, it is obvious that to Professor Camp a collecting expedition, whether his own or somebody else's, is a thrilling experience. Even the concise comments in this little manual communicate some of the thrill to the reader and the illustrations are equally effective.

The laboratory methods described nearly all involve delicate, tedious work, such as requires a great deal of patience, skill, and experience. Men capable of becoming first-class preparators, it would seem, are about as rare as geniuses in any other field. Several kinds of tools are described in addition to hammers and chisels, and much information is given on such subjects as modeling, casting, drawing, photography, cataloguing, storage, and the preparation of exhibits.

Some attention is given to the "diseases" that attack specimens. Thus, "pyrites disease" recently played such havoc with the wonderful *Iguanodon* skeletons of Brussels as to require elaborate and expensive remedies.

In Part II, Dr. Hanna draws upon his broad experience in collecting and studying invertebrate fossils of nearly all kinds and sizes. Considerable space is devoted to the methods in use in California oil-company laboratories for the study of Foraminifera, a subject in which Dr. Hanna himself was a distinguished pioneer. He is also a past master of the art of preparing, studying, and photographing diatoms, and gives a brief but interesting account of his methods. Other subjects discussed include the preparation of fish scales, otoliths, conodonts, and several other types of small invertebrates. In all cases, references are given to recent authoritative discussions published by other workers.

The space devoted to larger invertebrates is small, probably because most of the methods involved are fairly simple and relatively well known. There are good descriptions of a few of the more complex methods in use, with references to fuller discussions elsewhere when any are available.

GEOLOGY AND BIOLOGY OF THE SAN CARLOS MOUNTAINS TAMAULIPAS, MEXICO

DIRECTED BY LEWIS BURNETT KELLUM[1]

REVIEW BY PHILIP B. KING[2]
Washington D. C.

"Geology and Biology of the San Carlos Mountains, Tamaulipas, Mexico: Reports of the University of Michigan Expedition to the San Carlos Mountains in 1930." Directed by LEWIS BURNETT KELLUM. *University of Michigan Studies*, Sci. Ser., Vol. 12 (1937). 341 and xi pp. University of Michigan Press, Ann Arbor. Illus. Cloth. Approx. 8×11 inches. Price, $5.00.

[1] Manuscript received, February 14, 1938. Published by permission of the director, Geological Survey.

[2] U. S. Geological Survey.

This handsome volume, beautifully printed and illustrated, is not only a thorough scientific discussion of an interesting and little known area, but also an attractive piece of bookmaking, of which its publishers, the University of Michigan Press, and the authors, may well be proud.

The report represents the results of field investigation in the region in the summer of 1930 by a party of 7 members, 5 of whom were geologists. The investigation was sponsored by the University of Michigan, although the personnel included members from other universities, and was aided by grants from the National Research Council. For use in preparing the report, the results of earlier studies in the region for petroleum companies by Mr. Kellum were made available. The report consists of 9 chapters by members of the expedition and also by others on general and special phases of the San Carlos Mountains.

I. Geology of the Sedimentary Rocks of the San Carlos Mountains, by L. B. Kellum
II. Igneous Rocks of the San Carlos Mountains, by E. H. Watson
III. Ore Deposits of the San Carlos Mountains, by E. S. Bastin
IV. Geology of the Sierra de Cruillas, by R. W. Imlay
V. Mammals of the San Carlos Mountains and Vicinity, by L. R. Dice
VI. Arachnida from the San Carlos Mountains, by A. M. Chickering
VII. Two New Tarantulas of the Genus *Eurypelma* from the San Carlos Mountains, by R. T. Chamberlin
VIII. Fishes from the San Carlos Mountains, by C. L. Hubbs
IX. Some Amphibians and Reptiles from Tamaulipas, by H. T. Gage

The geological chapters occupy the greater part of the volume. The two by Kellum and Imlay are of greatest value to petroleum geologists, but the other geological chapters and the biological chapters are of interest in providing a setting for the stratigraphy.

The Sierra de San Carlos is a group of low, plateau-like mountains and scattered higher peaks which rise from the inner edge of the Coastal Plain of northeastern Mexico. It lies about 175 miles southwest of Brownsville, Texas, and about 25 miles east of the Sierra Madre. Structurally, it is a broad uplift, by which older Cretaceous limestones are raised to view. These are more resistant to erosion than the younger Cretaceous and Tertiary shales exposed in the surrounding plains. The higher peaks in the mountains consist of intrusive masses of igneous rock, and of limestones upturned along their flanks. The mountains have attracted attention since the Spanish days on account of silver and copper deposits associated with the intrusive masses. The mining of silver and copper ores has been carried on for more than 150 years, but most of the early production was from comparatively rich deposits near the surface, and activity has dwindled now that the workings have entered the leaner deposits below.

The strata exposed in the Sierra de San Carlos are chiefly of Lower and Upper Cretaceous age. The sequence resembles that in the Tampico region on the south and the same formation names are applicable. Three formations are distinguished. At the base is the Tamaulipas limestone, corresponding with the Fredericksburg and Washita groups of the Lower Cretaceous of Texas. Overlying it is the San Felipe limestone which is correlated with the Woodbine, Eagle Ford, and Austin formations of the Upper Cretaceous of

Texas. At the top, underlying the plains on the flanks of the mountains, is the Mendez shale, which is correlative with the higher Upper Cretaceous formations of Texas.

The base of the sedimentary column in the mountains is not visible, and the age of the oldest beds exposed is still uncertain. The early idea that the mountains contain outcrops of Paleozoic rocks has been disproved, but not the possible existence of Jurassic, Neocomian, and lowest Albian rocks. Rocks of these ages have been reported from the mountains by Burckhardt, on the basis of fossils sent to him, and by Böse and Cavins, on the basis of field observations. The University of Michigan expedition, however, obtained no fossils of such ages. Instead, most of the collections from below the top of the Tamaulipas limestone proved to be of middle Albian age, and the maximum exposed thickness of Tamaulipas and possible older rocks was found to be no more than 1,000 feet.

Kellum has, however, re-examined the fossils from the mountains that were originally studied by Burckhardt, and has confirmed the age determinations that Burckhardt made. It would thus appear that the mountains contain some exposures of rocks older than the Tamaulipas limestone. Their occurrence at the base of a thin Lower Cretaceous sequence is the more surprising since the thickness of the post-Neocomian Lower Cretaceous limestone in the near-by Sierra Madre on the west is about 3,000 feet.

The Lower Cretaceous sequence in the mountains thus appears to be greatly reduced in thickness, as though during Lower Cretaceous time the mountain area was a region of less active subsidence than the Sierra Madre geosyncline on the west. Kellum suggests

> that deposition of calcareous sediments in the area was comparatively slow . . . , due to the absence of conditions favorable for the precipitation of calcium carbonate, or to slow subsidence of the sea bottom which remained at or slightly above the profile of equilibrium (pp. 49–50).

The higher formations of the Cretaceous were originally deposited continuously over the present mountain area, as is shown by the large areas of San Felipe limestone still exposed there, and by the small remnants of Mendez shale at places where it was protected from erosion. The only younger beds in the area are Eocene strata that overlie the Mendez on the flanks of the mountains, and the Reynosa formation, of late Tertiary age, which extends up to their eastern base. The Reynosa is a terrestrial deposit, laid down after the mountains had been uplifted.

As already noted, the rocks of the Sierra de San Carlos have been lifted high above the relatively undisturbed beds that surround them in the plains. The rocks in the mountains are, however, much less disturbed than those of the intensely folded Sierra Madre on the west. The uplift is one of several in northeastern Mexico that lie between the Sierra Madre and the Coastal Plain, and it is more or less connected, by a series of low plateaus, with the next uplift on the south, the Sierra Tamaulipas.

The Sierra de San Carlos is structurally much more complex than the similarly placed broad uplifts on the north and south. Instead of trending parallel with the Sierra Madre, as most of them do, its longer axis trends west-northwest. The same trend is followed by a series of broad folds and gentle flexures that extend across the uplift, pitching beneath the younger beds at either end. The west-northwest folds are nearly in line with the prominent

series of east-west folds within the Sierra Madre between Monterrey and Torreon, which have been described in previous papers by Kellum and his associates.[3]

Distributed irregularly across the uplift are steep-sided domes caused by the intrusion of igneous rocks. These are believed by Kellum to have been formed subsequent to the development of the west-northwest-trending structural features.

Several geologists have previously considered the Sierra de San Carlos to be a structural continuation of the Sierra Tamaulipas, but Kellum mentions at one place that he believes this to be incorrect.

> The former range is not a continuation of the north-south anticline of the Sierra Tamaulipas, but belongs to a belt of east-west folding which is probably of different age (p. 35).

The reviewer wishes that this point had been further elaborated, since he has wondered many times about the stages in the structural history of northeastern Mexico, and about the time relations of the structural features of different trends. Although lacking personal knowledge of the region, he ventures to ask whether the west-northwest folding might not have taken place before the uplift of the San Carlos Mountains themselves, since the folds pitch down at either end, and whether the uplift might not correspond with the folding of the closely adjacent Sierra Tamaulipas on the south.

Watson's chapter describes the igneous rocks in detail. The larger intrusive masses of igneous rocks, some of which are 5 miles or more across, are laccolithic in form. Their structure, however, is complex in detail, for "their bases are often as much deformed as the overlying cover, and they tend more to have the form of a large, thick lens" (p. 107). Associated with the larger intrusions are numerous sills, dikes, and plugs, some of which also intrude the rocks of the plains beyond the mountain area. Lying in some of the mountain valleys are patches of extrusive basalt and agglomerate which seem to be younger than the intrusives.

The igneous rocks were intruded during two distinct epochs, both of which are probably of Tertiary age. The rocks of both epochs are chiefly fine-textured or porphyritic, and both are notably alkalic in composition. The rocks of the older epoch include alkalic gabbros, quartz-monzonites, and microgranites. Those of the younger epoch are "a complicated, very variable suite of uniformally alkalic rocks." These intrude both the igneous rocks of the older epoch and the surrounding sedimentary rocks, and have produced extensive contact metamorphism.

The silver and copper deposits, which are discussed by Bastin, are closely related to the intrusives, occurring either near the edges of the igneous rocks, or in the adjacent sedimentary rocks. They are believed to have been brought in by solutions associated with the magmas.

The chapter by Dice includes observations, not only on the mammals, but also on the ecology of the plants and animals in general. The Sierra de San Carlos belongs in the Tamaulipas biotic province, which embraces the semi-arid Coastal Plain of northeastern Mexico and extends into southern

[3] L. B. Kellum, R. W. Imlay, W. G. Kane, W. A. Kelley, and Q. D. Singewald, "Evolution of the Coahuila Peninsula, Mexico," *Bull. Geol. Soc. America*, Vol. 47 (1936), pp. 969–1176. Review in *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21 (1937), pp. 1206–11.

Texas. The mountains themselves form an island-like area of somewhat different type from the rest of the province, and more like the Sierra Madre area on the west. It is clothed in oak and pine forest, and has its own distinct community of animals.

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AFRICA

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*"Les Recherches de Petrole en Tunisie" (The Search for Petroleum in Tunis), by Alfred Roux and Marcel Solignac. *Annales des Combustibles Liquides*, No. 5 (September-October, 1937), pp. 865–904; 3 geologic maps.

CALIFORNIA

*"Geology of Ten Section Field Is Interesting," by H. T. Wyatt and A. S. Baptie. *Oil Weekly* (Houston), Vol. 88, No. 5 (January 10, 1938), pp. 67–69.

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GERMANY

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Southwest Germany. II. Jurassic), by Manfred Frank. *Geol. Rundschau* (Stuttgart), Bd. 28, Heft 8 (December 28, 1937), pp. 561–99; 7 figs. Contains correlation charts and cross sections.

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*"Illinois No Great Market Threat Despite Its Publicity," by John C. Albright. *Oil Weekly* (Houston), Vol. 88, No. 5 (January 10, 1938), pp. 81–82. Includes section across southern Illinois through Monroe, Clinton, and Lawrence counties, showing the LaSalle anticline and broad Illinois Basin, and a stratigraphic table of oil- and gas-producing strata in Illinois.

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*"Discovery of *Orbitolina*-bearing Rocks in Burma," by M. R. Sahni. *Records Geol. Survey India* (Calcutta), Vol. 71, Pt. 4 (1937), pp. 360–75; 2 pls.

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NEW YORK AND PENNSYLVANIA

*"Analyses of Crude Oils from Some Fields of Pennsylvania and New York," by E. C. Lane and E. L. Garton. *U. S. Bur. Mines R. I. 3385* (Washington, D.C., January, 1938). 68 mim. pp.

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VENEZUELA

**Boletin de Geologia y Mineria*, Tomo 1, Nos. 2, 3, 4 (April, July, October, 1937), official publication of the Servicio Técnico de Geologia y Mineria, Caracas. Edition in English of the papers presented at the First Venezuelan Geological Congress at Caracas in February, 1937. "Geological Notes on the Central Part of the Cordillera de la Costa, Venezuela," by Santiago E. Aguerrevere and Guillermo Zuloaga. "Contribution to the Geology of the Venezuelan Andes," by Victor Oppenheim. "Some Observations on Cretaceous and Pre-Cretaceous Beds in the Southwestern and Northern Central Parts of Venezuela," by L. Kehrer. "Synopsis of the Geologic Formations of the Western Part of the Maracacibo Basin, Venezuela," H. D. Hedberg and L. C. Sass. "Notes on the Stratigraphy of the Bolivar Coastal Fields, Maracaibo Basin, Venezuela," by Merril W. Haas and Ralph G. Hubman. "Stratigraphy and Paleontology of Mene Grande and Vicinity," by G. E. Tash. "The Stratigraphy of West Buchivacoa, Venezuela," by G. W. Halse. "General Geology and Stratigraphy of Cumarebo Area, State of Falcon," by Clemente González de Juana. "Comparison of Maturin and Maracaibo Sedimentary Basin, Venezuela," by C. Wiedenmayer. "Stratigraphy of the Rio Querecual Section of Northeastern Anzoategui, Venezuela," H. D. Hedberg. "The Geologic Sections of the Barinas Region: Districts of Barinas, Bolivar and Obispos, State of Zamora, Venezuela," by A. N. Mackenzie. "Geologic Notes on the 'Punta Gavilan' Formation and on the Eastern Part of State of Falcon," by H. N. Suter. "Large Fossil Mammals from the Barquisimeto Area," by H. Nectario María.

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*"Topographic Map, Greenbrier County," *West Virginia Geol. Survey* (1936). Scale, 1:62,500. 39×59 inches. Paper. Price, $0.75.

*"Geological Map, Greenbrier County," *West Virginia Geol. Survey* (1937). Scale, 1:62,500. 39×59 inches. Paper. Price, $1.00.

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"Geology and Natural Resources of West Virginia, 1938," by Paul H. Price, R. C. Tucker, and O. L. Haught. *West Virginia Geol. Survey.*, Vol. 10 (Morgantown, 1938). Approx. 450 pp., profusely illustrated. Price, $2.00.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 22, NO. 3 (MARCH, 1938), PP. 326-384

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Theron Wasson
Paul Weaver
A. W. Weeks
A. C. Wright

FINANCIAL STATEMENT, 1937

To the Executive Committee,
The American Association of Petroleum Geologists,
Tulsa, Oklahoma.
DEAR SIRS:

We have made an examination of the accounting records of THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS for the year ended December 31, 1937, and now submit our report thereon together with the following statements:

Exhibit

A	Statement of Financial Condition at December 31, 1937
B	Statement of Income for the year ended December 31, 1937

Schedule

*1	Investments at December 31, 1937
2	Statement of Income from Publications for the year ended December 31, 1937
3	Statement of General and Administrative Expenses for the year ended December 31, 1937

In connection with the examination, we examined or tested the accounting records of the Association and other supporting evidence and obtained information and explanations from employees of the Association. We also made a general review of the accounting methods and of the operating and income accounts for the year, but we did not make a detailed audit of the transactions.

Demand Deposits were reconciled to certificates received directly from the depositories. Reserve of $949.16, provided for doubtful accounts receivable, appears adequate. Inventory of Publications, in the net amount of $19,986.81, represents quantities as shown by the records, stated at appraised values in accordance with resolution adopted by the Executive Committee and represents publications required for anticipated needs. Investments and accrued interest thereon are listed in Schedule *1*. A confirmation of Investments at December 31, 1937, addressed to us in care of Ira H. Cram, Association Treasurer, was obtained from The New York Trust Company, Custodian. Accrued Printers' Charges of $263.83 represent accrued charges to December 31, 1937, in connection with the printing of *Miocene Stratigraphy of California*.

In our opinion, based on such examination and subject to the foregoing, the accompanying Statement of Financial Condition and related Statement of Income, together with the Schedules attached thereto, fairly present the financial position of the Association at December 31, 1937, and the results of its operations for the year ended that date.

(Signed) ARTHUR YOUNG & COMPANY, *Accountants and Auditors*
TULSA, OKLAHOMA
February 2, 1938

* Schedule *1* is not here published

EXHIBIT A
STATEMENT OF FINANCIAL CONDITION AT DECEMBER 31, 1937

ASSETS	*General Fund*	*Publication Fund*	*Research Fund*	*Total*
CURRENT ASSETS:				
Demand Deposits:				
The First National Bank and Trust Company, Tulsa, Oklahoma	$ 7,655.37	$ 5,840.31	$ —	$13,495.68
National Bank of Commerce, Tulsa, Oklahoma	421.03	—	—	421.03
TOTAL CASH IN BANKS	$ 8,076.40	$ 5,840.31	$ —	$13,916.71
Accounts Receivable:				
Membership Dues (*Less* Reserve $532.50)	$ 542.35	$ —	$ —	$ 542.35
Advertising	582.49	—	—	582.49
Due from The New York Trust Company	602.93	159.00	—	761.93
Other Accounts Receivable (*Less* Reserve $416.66)	718.72	411.01	—	1,129.73
TOTAL ACCOUNTS RECEIVABLE	$ 2,446.49	$ 570.01	$ —	$ 3,016.50
Accrued Interest Receivable (*Less* Reserve $314.16)	$ 336.32	$ 73.45	$ 24.36	$ 434.13
Inventory of Publications—at Cost	$34,214.89	$ 7,431.78	$ —	$41,646.67
Less: Reserve	21,659.86	—	—	21,659.86
NET VALUE OF PUBLICATIONS	$12,555.03	$ 7,431.78	$ —	$19,986.81
Special Publications in Process:				
Miocene Stratigraphy of California	$ —	$ 406.33	$ —	$ 406.33
TOTAL CURRENT ASSETS	$23,414.24	$14,321.88	$ 24.36	$37,760.48
INVESTMENTS:				
At Cost (Market Value $51,135.89)	$44,431.55	$12,712.46	$1,545.57	$58,689.58
FURNITURE AND FIXTURES	$ 4,127.20	$ —	$ —	$ 4,127.20
Less: Reserve for Depreciation	3,069.59	—	—	3,069.59
NET VALUE OF FURNITURE AND FIXTURES	$ 1,057.61	$ —	$ —	$ 1,057.61
PREPAID AND DEFERRED CHARGES	$ 66.32	$ —	$ —	$ 66.32
TOTAL ASSETS	$68,969.72	$27,034.34	$1,569.93	$97,573.99

LIABILITIES AND SURPLUS	*General Fund*	*Publication Fund*	*Research Fund*	*Total*
CURRENT LIABILITIES:				
Accounts Payable	$ 1,144.96	$ —	$ —	$ 1,144.96
Accrued Printers' Charges	—	263.83	—	263.83
TOTAL CURRENT LIABILITIES	$ 1,144.96	$ 263.83	$ —	$ 1,408.79
DEFERRED INCOME:				
Memberships and Subscriptions:				
Active Memberships	$ 2,752.50	$ —	$ —	$ 2,752.50
Associate Memberships	776.00	—	—	776.00
Subscriptions to Bulletin	2,587.75	—	—	2,587.75
	$ 6,116.25	$ —	$ —	$ 6,116.25
Other Deferred Income	537.50	—	—	537.50
TOTAL DEFERRED INCOME	$ 6,653.75	$ —	$ —	$ 6,653.75
SURPLUS:				
Balance, December 31, 1936	$59,131.51	$24,394.36	$1,504.30	$85,030.17
Net Income for the Year ended December 31, 1937 (Exhibit *B*)	2,039.50	2,376.15	65.63	4,481.28
Balance, December 31, 1937	$61,171.01	$26,770.51	$1,569.93	$89,511.45
TOTAL LIABILITIES AND SURPLUS	$68,969.72	$27,034.34	$1,569.93	$97,573.99

SUBJECT TO COMMENTS IN ACCOMPANYING REPORT

EXHIBIT B

STATEMENT OF INCOME FOR THE YEAR ENDED DECEMBER 31, 1937

	General Fund				Publication Fund		Research Fund		Total	
OPERATING INCOME:										
Dues for Current Period:	*Members*	*Annual Dues*								
Associate Membership:										
Less than Three Years	310	$ 6.00	$ 1,860.00		$ —		$ —		$ 1,860.00	
Three to Six Years	47	8.00	376.00		—		—		376.00	
Over Six Years	131	10.00	1,310.00		—		—		1,310.00	
	488			$ 3,546.00		$ —		$ —		$ 3,546.00
Active Membership	1,988	10.00		19,880.00		—		—		19,880.00
	2,476			$23,426.00		$ —		$ —		$23,426.00
Less: Transferred to "Income from Publications"										
Associate Membership	488	$ 6.00	$ 2,928.00		$ —		$ —		$ 2,928.00	
Active Membership	1,988	6.00	11,928.00		—		—		11,928.00	
	2,476			14,856.00		—		—		14,856.00
				$ 8,570.00		$ —		$ —		$ 8,570.00
Net Income from Publications (Schedule 2)				5,850.78		2,206.94		—		8,057.72
Convention Receipts (Net)				*−388.25*		—		—		*−388.25*
				$14,032.53		$2,206.94		$ —		$16,239.47
GENERAL AND ADMINISTRATIVE EXPENSES (Schedule 3)				15,063.26		332.57		—		15,395.83
NET OPERATING INCOME—*Loss*				$−1,030.73		$1,874.37		$ —		$ 843.64
NON-OPERATING INCOME:										
Income from "Investments"			$ 2,074.47		$501.78		$65.63		$ 2,641.88	
Miscellaneous			29.47		—		—		29.47	
				2,103.94		501.78		65.63		2,671.35
NET INCOME BEFORE EXTRAORDINARY ITEMS				$ 1,073.21		$2,376.15		$65.63		$ 3,514.99
EXTRAORDINARY ITEMS:										
Recovery of Interest on "Investments" for prior years			$ 160.00		$ —		$ —		$ 160.00	
Recovery of Delinquent Dues previously charged off			544.00		—		—		544.00	
Collections from Reinstated Members			210.10		—		—		210.10	
Sale of Library			56.50		—		—		56.50	
			$ 970.60		$ —		$ —		$ 970.60	
Less: Net Loss on Disposal of "Investments"			4.31		—		—		4.31	
				966.29		—		—		966.29
NET INCOME FOR THE PERIOD				$ 2,039.50		$2,376.15		$65.63		$ 4,481.28

SUBJECT TO COMMENTS IN ACCOMPANYING REPORT

SCHEDULE 2

STATEMENT OF INCOME FROM PUBLICATIONS FOR THE YEAR ENDED DECEMBER 31, 1937

	General Fund		*Publication Fund*		*Total*	
OPERATING INCOME:						
Dues Transferred		$14,856.00		$ —		$14,856.00
Bulletin Subscriptions		4,531.94		—		4,531.94
Advertising		7,084.95		—		7,084.95
Sale of Bound Volumes and Special Publications:						
Bound Volumes	$ 2,911.60		$ —		$ 2,911.60	
Back Numbers	1,136.97		—		1,136.97	
Structure Volume I	—		135.30		135.30	
Structure Volume II	617.05		—		617.05	
Geology of California	—		196.24		196.24	
Problems of Petroleum Geology	1,023.80		—		1,023.80	
Geology of Natural Gas	—		917.14		917.14	
Geology of Tampico Region	—		667.46		667.46	
Alberta Symposium	34.80		—		34.80	
Comprehensive Index	448.36		—		448.36	
Gulf Coast Oil Fields	—		4,197.86		4,197.86	
Structural Evolution of Southern California	—		1,117.13		1,117.13	
Other Publications	135.90	6,308.48	107.87	7,339.00	243.77	13,647.48
TOTAL OPERATING INCOME		$32,781.37		$7,339.00		$40,120.37
COSTS AND EXPENSES:						
Proportion of Manager's Salary	$ 2,925.00		$ —		$ 2,925.00	
Editorial Salaries	3,495.22		—		3,495.22	
Printing Bulletins	12,144.88		—		12,144.88	
Engraving	1,695.20		—		1,695.20	
Stencil Corrections and Mailing	184.36		—		184.36	
Bulletin Mailing and Express	887.76		—		887.76	
Copyright Fees	24.00		—		24.00	
Printing Separates	246.59		—		246.59	
Binding	409.04		—		409.04	
Salaries Applicable to Bulletin Index	1,112.85		—		1,112.85	
Printing and Binding Bulletin Index	3,360.98		—		3,360.98	
Other Publications—Freight, Express and Postage	772.78		570.77		1,343.55	
Evolution of Southern California—Printing and Other Costs	—		1,220.65		1,220.65	
Gulf Coast Oil Fields—Printing and Other Costs	—		4,104.99		4,104.99	
Miscellaneous	221.45		—		221.45	
	$27,480.11		$5,896.41		$33,376.52	
Deduct:						
Inventory Increase	549.52		764.35		1,313.87	
TOTAL COSTS AND EXPENSES		26,930.59		5,132.06		32,062.65
NET INCOME FROM PUBLICATIONS FOR THE PERIOD		$ 5,850.78		$2,206.94		$ 8,057.72

SUBJECT TO COMMENTS IN ACCOMPANYING REPORT

SCHEDULE 3

STATEMENT OF GENERAL AND ADMINISTRATIVE EXPENSES
FOR THE YEAR ENDED DECEMBER 31, 1937

GENERAL FUND:		
Proportion of Manager's Salary		$ 2,782.50
Clerical Salaries		5,675.69
Office Rent		1,460.00
Postage		1,315.62
Office Supplies and Expenses		501.51
Donations:		
Society of Economic Geologists	$250.00	
Society of Economic Paleontologists and Mineralogists	500.00	
		750.00
Printing and Stationery		440.16
Telephone and Telegraph		444.58
Freight and Express		254.17
Insurance		155.14
Audit Expense		300.00
Investment Counsel		300.00
Bad Debts		174.13
Miscellaneous		116.37
Depreciation of Furniture and Fixtures		393.39
		$15,063.26
PUBLICATION FUND:		
Investment Counsel		$ 100.00
Bad Debts		95.18
Miscellaneous		137.39
		$ 332.57
TOTAL GENERAL AND ADMINISTRATIVE EXPENSES		$15,395.83

SUBJECT TO COMMENTS IN ACCOMPANYING REPORT

FINANCIAL STATEMENT, DIVISION OF PALEONTOLOGY AND MINERALOGY, 1937

To the Council,
Society of Economic Paleontologists
and Mineralogists,
Tulsa, Oklahoma.

DEAR SIRS:

We have made an examination of the accounting records of the Society of Economic Paleontologists and Mineralogists for the year ended December 31, 1937, and now submit our report thereon together with the following statements:

Exhibit

A Statement of Financial Condition at December 31, 1937
B Statement of Income for the year ended December 31, 1937

Schedule

1 Statement of Receipts and Disbursements for the year ended December 31, 1937

In connection with the examination, we examined or tested the accounting records of the Society and other supporting evidence and obtained information and explanations from employees of the Society, but we did not make a detailed audit of the transactions. In our opinion the accounting records are inadequate to completely account for the assets of and the income accruing to the Society, nor do they provide for sufficient classification of expenses. Our recommendations with respect to suggested changes in the accounting records have been discussed with Mr. J. P. D. Hull, Business Manager of the Society.

Demand and Savings Deposits were reconciled to certificates received directly from the depositories. Bad Debts in the amount of $293.10, representing uncollected balances of Accounts Receivable, for which details of the items comprising such balances were not available, have been excluded from Accounts Receivable and charged to Income.

Inventory of Publications represents approximately 29,000 journals (exclusive of journals in excess of complete sets for issues prior to 1937) as shown by the records, including certain issues printed at the expense of the Paleontological Society for the years 1935, 1936 and 1937, stated at appraised values of 50¢ each for journals printed prior to 1937 and cost to either the Society of Economic Paleontologists and Mineralogists or the Paleontological Society for journals printed in 1937. The reduction in inventory value of $13,457.00 occasioned by the foregoing method of inventory valuation and by adjustments of quantities to agree with corrected inventory records has been charged to Surplus. We are unable to express an opinion with respect to ultimate realization from the Inventory.

(Signed) ARTHUR YOUNG & COMPANY, *Accountants and Auditors*

TULSA, OKLAHOMA
February 19, 1938

EXHIBIT A
STATEMENT OF FINANCIAL CONDITION
AT DECEMBER 31, 1937

ASSETS

CURRENT ASSETS:		
Demand Deposits—		
The First National Bank and Trust Company, Tulsa, Oklahoma	$ 2,216.81	
National Bank of Commerce, Tulsa, Oklahoma	154.77	$ 2,371.58
Savings Deposits—		
The First National Bank and Trust Company, Tulsa, Oklahoma		1,007.37
Accounts Receivable—		
Printed Matter	$ 285.80	
Advertising	180.00	
Other Accounts Receivable	38.45	504.25
Inventory of Publications (Quantities and Values determined by the Management)		14,641.03
TOTAL CURRENT ASSETS		$18,524.23
FURNITURE AND FIXTURES		205.24
TOTAL ASSETS		$18,729.47

LIABILITIES AND SURPLUS

CURRENT LIABILITIES:		
Accounts Payable		$ 1,089.86
DEFERRED INCOME:		
1938 Subscriptions—		
Journal of Paleontology	$ 1,007.07	
Journal of Sedimentary Petrology	345.20	
1938 Membership Dues	134.00	1,486.27
SURPLUS:		
Balance per Books, December 31, 1936	$27,245.32	
Less: Adjustment of Inventory of Publications	13,457.00	
Adjusted Balance, December 31, 1936	$13,788.32	
Net Income for the year ended December 31, 1937 (Exhibit *B*)	2,365.02	
Balance December 31, 1937		16,153.34
TOTAL LIABILITIES AND SURPLUS		$18,729.47

SUBJECT TO COMMENTS IN ACCOMPANYING REPORT

EXHIBIT B

STATEMENT OF INCOME
FOR THE YEAR ENDED DECEMBER 31, 1937

OPERATING INCOME:			
Subscriptions and Dues—			
Subscriptions—			
Journal of Paleontology		$2,161.47	
Journal of Sedimentary Petrology		697.02	
		$2,858.49	
Dues—Associate Membership		100.00	
		$2,958.49	
Sale of Back Numbers—			
Journal of Paleontology	$ 509.60		
Journal of Sedimentary Petrology	239.05	748.65	
Advertising		420.00	
Other Operating Income		266.70	$4,393.84
COSTS AND EXPENSES:			
Printing Journals—			
Journal of Paleontology	$2,944.78		
Journal of Sedimentary Petrology	854.67	$3,799.45	
Binding and Plates		150.79	
Editorial Salaries		120.00	
Clerical Salaries		323.50	
Office Supplies and Expenses		342.17	
Postage and Mailing		305.21	
Freight and Express		115.47	
Other Costs and Expenses		103.02	
		$5,259.61	
Deduct:			
Inventory Value (Cost) of Journals printed in 1937, included in Inventory of Publications		1,544.70	3,714.91
			$ 678.93
NON-OPERATING INCOME:			
Donations—			
The American Association of Petroleum Geologists		$ 500.00	
National Research Council		80.00	
		$ 580.00	
Interest on Investments		21.86	
Inventory Value of Journals, printed in 1937, at expense of the Paleontological Society, included in Inventory of Publications		1,377.33	1,979.19
			$2,658.12
INCOME DEDUCTIONS:			
Bad Debts			293.10
NET INCOME			$2,365.02

SUBJECT TO COMMENTS IN ACCOMPANYING REPORT

SCHEDULE 1

STATEMENT OF RECEIPTS AND DISBURSEMENTS
FOR THE YEAR ENDED DECEMBER 31, 1937

Demand Deposits, December 31, 1936			$ 993.62
Receipts:			
Transfer of Funds from Savings Account		$ 700.00	
Cancellation of Check Outstanding at December 31, 1936		1.00	
Accounts Receivable		393.60	
1937 Dues and Subscriptions—			
Journal of Paleontology	$1,938.67		
Journal of Sedimentary Petrology	648.42		
Associate Membership Dues	100.00	2,687.09	
Sale of Back Numbers—			
Journal of Paleontology	$ 509.60		
Journal of Sedimentary Petrology	239.05	748.65	
Donations—			
The American Association of Petroleum Geologists	$ 500.00		
National Research Council	80.00	580.00	
Advertising		240.00	
1938 Subscriptions—			
Journal of Paleontology	$1,007.07		
Journal of Sedimentary Petrology	345.20	1,352.27	
1938 Membership Dues		134.00	
Miscellaneous		228.25	7,064.86
			$8,058.48
Disbursements:			
Printing and Mailing Journals—			
Journal of Paleontology	$3,533.16		
Journal of Sedimentary Petrology	825.58	$4,358.74	
Plates, Reprints and Binding		223.47	
Office Salaries		443.50	
Office Supplies and Expenses		287.87	
Postage		140.43	
Freight and Express		115.47	
Refunds of Subscriptions		14.40	
Miscellaneous		103.02	5,686.90
Demand Deposits, December 31, 1937			$2,371.58

SUBJECT TO COMMENTS IN ACCOMPANYING REPORT

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
MEMBERSHIP LIST

MARCH 4, 1938

HONORARY MEMBERS

The executive committee may from time to time elect as honorary members persons who have contributed distinguished service to the cause of petroleum geology. Honorary members shall not be required to pay dues.—*Sec. 6, Article III, of the Constitution.*

LIFE MEMBERS

The executive committee may grant life membership to members who have paid their dues and are otherwise qualified.—*Sec. 2, Article III, of the Constitution.*

On the payment of two hundred dollars ($200.00) any member in good standing shall be declared a life member and thereafter shall not be required to pay annual dues. —*Sec. 2, Article I, of the By-Laws.*

MEMBERS

Any person engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership, provided he is a graduate of an institution of collegiate standing, in which institution he has done his major work in geology, or in sciences fundamental to petroleum geology, and in addition has had the equivalent of three years' experience in petroleum geology or in the application of these other sciences to petroleum geology or to research in petroleum geology or technology; and provided further that in the case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee, and provided further that these requirements shall not be construed to exclude teachers and research workers in recognized institutions whose work is of such character as in the opinion of the executive committee shall qualify them for membership.

Active members alone shall be known as members.—*Sec. 1, Article III, of the Constitution.*

ASSOCIATES

Any person having completed as much as thirty hours of geology (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalent to this, is eligible to associate membership, provided at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing, or shall be engaged in petroleum geology; and any person who is a graduate of an institution of collegiate standing, in which he has done his major work in sciences fundamental to petroleum geology or petroleum technology, and who has had the equivalent of one year's experience in the application of his science to the study of petroleum geology, shall be eligible to associate membership, provided at the time of his application for membership he shall be engaged in investigations in the broader subject of petroleum geology and technology.

Associate members shall be known as associates.

Associates shall enjoy all the privileges of membership in the Association, save that they shall not hold office, sign applications for membership, or vote; neither shall they have the privilege of advertising their affiliation with the Association in professional cards or professional reports or otherwise.—*Sec. 3, Article III, of the Constitution.*

HONORARY MEMBERS

(**Deceased)

Campbell, Marius R., 735 Fourth Ave., St. Petersburg, Fla.
Darton, N. H., U. S. Geological Survey, Washington, D. C.
Decker, Charles E., 508 Chautauqua Ave., Norman, Okla.
**Dumble, E. T.
Goodrich, Harold B., 1628 S. Cincinnati, Tulsa, Okla.
Harris, Gilbert D., Dept. of Geology, Cornell University, Ithaca, N. Y.
Hill, Robert T., c/o Dallas News, Dallas, Tex.
Lawson, Andrew C., University of California, Berkeley, Calif.
Mendenhall, Walter C., U. S. Geological Survey, Washington, D. C.
Orcutt, W. W., Union Oil Company Bldg., Los Angeles, Calif.
Ordoñez, Ezequiel, Abraham Gonzales 79, Mexico City, Mexico
**Salisbury, R. D.
Schuchert, Charles, Yale University, New Haven, Conn.
Smith, George Otis, Box 308, Skowhegan, Me.
Stille, Hans, Geological Institute, University of Berlin, Berlin, Germany
Taff, Joseph A., 628 Cowper St., Palo Alto, Calif.
**Udden, Johan August
Ulrich, E. O., National Museum, Washington, D. C.
van der Gracht, W.A.J.M., Staatstoezicht op de Mijnen, 96 Akerstraat Heerlen, Holland
**von Hofer, Hans Hofrat
**White, David
**White, I. C.

COMPLETE LIST OF MEMBERS, ASSOCIATES, HONORARY MEMBERS, AND LIFE MEMBERS

Honorary	16
Life	2
Members	2,068
Associates	573
Total	2,659

EXPLANATION OF SYMBOLS

* Honorary Member. † Life Member. ‖ Associate. Members are not marked. The year refers to the date of election to membership.

‖Abbott, John L., 1209 Fort Worth Natl. Bank Bldg., Fort Worth, Tex.....'27
Abraham, A. W., 305 N. Rosemont Blvd., San Gabriel, Calif.....'30
‖Absher, K. B., 4319 E. Lewis, Wichita, Kan.....'25
Absher, William F., Geol. Dept., Cities Service Oil Co., Bartlesville, Okla.....'20
Achning, Walter J., 910 Milam Bldg., San Antonio, Tex.....'38
Ackers, A. L., Stanolind Oil & Gas Co., Box 1410, Fort Worth, Tex.....'25
Adams, Elmo W., Honolulu Oil Corp., 215 Market St., San Francisco, Calif.....'30
Adams, Frank C., Gem Oil Co., 1506 Esperson Bldg., Houston, Tex.....'27
Adams, John Emery, Drawer R, Midland, Tex.....'29
‖Adams, Kilburn E., The Texas Co., Box 354, Oklahoma City, Okla.....'38
Adams, W. C., Deep Rock Oil Corp., Atlas Life Bldg., Tulsa, Okla.....'24
Addison, Carl C., Pure Oil Co., 402 Second Natl. Bank Bldg., Saginaw, Mich.....'30
Adkins, W. S., Shell Petr. Corp., Houston, Tex.....'20
‖Adkisson, Albert, 2019 W. T. Waggoner Bldg., Fort Worth, Tex.....'34
Adler, Joseph L., 2011 Experson Bldg., Houston, Tex.....'30
‖Agee, Flint H., 6115 Middleton, Huntington Park, Calif.....'38
Aguerrevere, Pedro I., Sur 3, No. 94, Caracas, Venezuela, S. A.....'24
Aguerrevere, Santiago E., Sur 3, No. 94, Caracas, Venezuela, S. A.....'24
Aimer, James D., Drawer 1734, Shreveport, La.....'26
Ainsworth, David, 146 S. Fountain Ave., Wichita, Kan.....'23
Aitken, W. Ernest, Ambalema, Colombia, S. A.....'32

Albertson, Maurice M., Shell Petr. Corp., Box 2099, Houston, Tex. . . . . '20
Albrecht, Helmuth, Burbach-Kaliwerke Aktiengesellschaft, Kaiser-Otto-Ring 9, Magdeburg, Germany . . . . . '32
Aldrich, G. Frank, Box 622, Midland, Tex. . . . . '25
Alexander, C. I., Magnolia Petr. Co., Drawer 872, Lake Charles, La. . . . . '27
Allan, John Andrew, University of Alberta, Edmonton, Alta., Canada . . . . . '30
Allan, Thomas H., 707 Bitting Bldg., Wichita, Kan. . . . . '24
Allen, Alton C., 2609 Wabash, Fort Worth, Tex. . . . . '35
Allen, Devere F., 3000 Sowers Court, Topeka, Kan. . . . . '29
Allen, Donald M., 3543 E. Douglas, Wichita, Kan. . . . . '24
Allen, E. G., 3912 Amherst St., Dallas, Tex. . . . . '17
‖Allen, Stanley R., 246 Humble Bldg., Houston, Tex. . . . . '35
Allen, Walter J., 811 S. Gary Pl., Tulsa, Okla. . . . . '18
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Cannon, Joe, 901 Western Reserve Bldg., San Angelo, Tex.....'28
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‖Carey, S. Warren, Oil Search Limited, 350 George St., Sydney, N. S. W.....'36
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Carlson, Edwin N., 500 Bitting Bldg., Wichita, Kan.....'24
Carlton, Dave P., Humble Oil & Refg. Co., 901 Humble Bldg., Houston, Tex.....'20
Carman, Katharine W., c/o E. DeGolyer, 610 Continental Bldg., Dallas, Tex.....'36
Carmody, Robert A., 3705 Edgemont Pl., Wichita, Kan.....'36
Carpenter, Charles B., 551 Federal Bldg., Dallas, Tex.....'34
Carpenter, Everett, 2104 Ong St., Amarillo, Tex.....'21
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‖Carpenter, Margaret C., 1217 Virginia Pl., Fort Worth, Tex.....'27
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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

At the February meeting of the American Institute of Mining and Metallurgical Engineers in New York, R. H. DURWARD, San Antonio, presented a paper, "The Use of Magnetic Data in Locating Oil Fields in Southwest Texas." F. B. PLUMMER, University of Texas, presented a paper, "Petroleum Engineering."

HANS STILLE, professor of paleontology at Berlin, has been elected secretary of the Prussian Academy of Sciences.

IRVING PERRINE, consulting geologist, Oklahoma City, spoke before a meeting of the Oklahoma City Geological Society, January 17, on the diamond mining industry of the United States.

ARMSTRONG PRICE spoke before the South Texas Geological Society, Corpus Christi, January 21, "Geology of the Rio Grande Delta."

A. S. BUNTE, formerly with the Shell Petroleum Corporation as division subsurface engineer at McPherson, Kansas, has opened consulting offices in the Brown Building, Wichita, Kansas.

At a meeting of the West Texas Geological Society, Midland, Texas, January 24, ROBERT ROTH presented a paper on the Custer formation.

DEAN METTS, Humble Oil and Refining Company, read a paper, "Geology of Roanoke Oil Field, Acadia Parish, Louisiana," before the Houston Geological Society, January 20.

BEN F. HAKE, Saginaw, recently elected president of the Michigan Geological Society, recently read a paper, "Crude Oil and Further Development of the Michigan Fields," before the Saginaw Valley Oil Men's Club.

HAROLD W. HAIGHT, formerly with the Huasteca Petroleum Company, Ebano, San Luis Potosi, Mexico, may now be addressed in care of the Standard Oil Company of Egypt, 22 Sharia Kasr, El Nil, Cairo, Egypt.

JOHN C. MILLER, chief geologist in south Texas division of The Texas Company, Houston, recently discussed oil-producing zones of the Gulf Coast before the Houston Geological Society.

JOSEPH MARSH CLARK resigned his position with the Gulf Oil Corporation, January 1, to accept a position in the geological department of the Tide Water Oil Company.

E. G. GAYLORD, Standard Oil Company of California, San Francisco, has been named 1938 chairman of the advisory committee on fundamental research on occurrence and recovery of Petroleum of the American Petroleum Institute's Division of Production. C. A. YOUNG, secretary of the Institute's Division of Production, Dallas, Texas, has been named secretary of the

committee. Members of the committee are as follows: F. R. Clark, The Ohio Oil Company, Tulsa; K. C. Heald, Gulf Oil Corporation, Pittsburgh; W. B. Heroy, Consolidated Oil Corporation, New York; F. H. Lahee, Sun Oil Company, Dallas; A. W. McCoy, Ponca City; C. V. Millikan, Amerada Petroleum Corporation, Tulsa; T. V. Moore, Humble Oil and Refining Company, Houston; K. B. Nowels, Forest Development Corporation, Abilene; R. D. Reed, The Texas Company of California, Los Angeles; R. B. Roark, Shell Petroleum Corporation, Tulsa; A. C. Rubel, Union Oil Company of California, Los Angeles; W. C. Shutts, Standard Oil Development Company, New York; H. D. Wilde, Jr. (alternate to T. V. Moore), Humble Oil and Refining Company, Baytown, Texas; and F. E. Wood, Standard Oil Company of Indiana, Chicago.

HARRY F. WRIGHT, consulting geologist and engineer, has changed his address to 301 Philtower, Tulsa.

Newly elected officers for the South Louisiana Geological Society, Lake Charles, are: JOHN F. MAHONEY, Union Sulphur Company, president; DEAN F. METTS, Humble Oil and Refining Company, vice-president; W. R. CANADA, Stanolind Oil and Gas Company, secretary; BAKER HOSKINS, Shell Petroleum Corporation, treasurer.

The Michigan Geological Society has elected new officers as follows: President, BEN F. HAKE, Gulf Refining Company, Saginaw; vice-president, E. A. NEWMAN, Department of Conservation, Lansing; secretary-treasurer, ROBERT W. BECK, Carter Oil Company, Saginaw; business representative, S. G. BERGQUIST, Michigan State College, East Lansing.

A. C. TESTER, University of Iowa, has been granted 2 years leave of absence to be engaged in exploration for the Socony Vacuum Oil Company in Colombia, South America.

HAL P. BYBEE, Austin, Texas, has been elected president of the Southwestern Geological Society. ROBERT C. REDFIELD, University of Texas, Austin, is secretary-treasurer.

GRAYDON LAUGHBAUM, Sinclair Prairie Oil Company, Oklahoma City, has returned from Miami, Florida.

JOHN S. IVY, Union Producing Company, presented a paper on the Rodessa field at a meeting of the South Louisiana Geological Society, January 24.

H. W. HAIGHT recently spoke before the Tulsa Geological Society weekly luncheon on the possibilities of oil production in northern Mexico.

W. L. GRAHAM is now with the Thompson Brothers, oil producers, Ada, Oklahoma.

E. E. PORTERFIELD is in charge of the Lane-Wells Company field office recently established at Seminole, Oklahoma, according to Bruce Barkis, manager of sales development.

At a meeting of the Tulsa Geological Society, February 7, LOUIS ROARK presented colored moving pictures of the Grand Canyon region, and CLARK MILLISON read a paper, "Geology of North Flank of Wichita Mountains."

ROY T. HAZZARD AND B. W. BLANPIED, Gulf Refining Company, Shreveport, presented "The Chickasawhay Problem in Southeast Mississippi and Its Subsurface Stratigraphic Importance in South Louisiana," before the Houston Geological Society, February 3.

J. EARLE BROWN, Amtex Petroleum Corporation, Fort Worth, has resigned to engage in consulting work, property inventories, and appraisals.

W. M. SMALL has been made general manager in western Egypt for the Standard Oil Company of Egypt. Small has served subsidiaries of the Standard Oil Company of New Jersey in Mexico, Argentina, and various European countries.

The following news about the geologists of the Amiranian Oil Company and the Inland Exploration Company was dated at Kabul on January 1. FREDERICK G. CLAPP had left Kabul to travel by way of India to Zahidan, in southeast Iran, and thence south to Chabahar, the proposed port for the Iranian Pipe-Line Company on the Arabian Sea. E. GARDNER CLAPP was in Kabul in December. HENRY CARTER REA went to Peshawar in December and was soon to return to Afghanistan. HOWARD M. KIRK worked 2 months in the north and moved south for the winter. ERNEST F. FOX made extensive mountain traverses in the Province of Badakhshan-Kataghan and was about to go to Kandahar. HUBERT G. SCHENCK was in southeastern Iran. LESTER S. THOMPSON was transferred to Zahidan (formerly Duzdab) in Sistan Province in January. FRANK REEVES was working in the Kavir, or great central desert of Iran. B. F. BUIE was moving from Tabbas, in central Iran, to Kandahar, in south-central Afghanistan. HENRY HOTCHKISS was in Meched in November and part of December, visiting his wife and newly born son; he moved south the first of the year for winter work. WALTER P. WILSON arrived from Australia in November and went immediately to central Iran to help Reeves on extensive plane-table surveys.

ROBERT T. HILL was elected to life membership in the Dallas Petroleum Geologists at the regular monthly luncheon held on February 7, 1938. The resolution adopted by the society follows.

Be It Resolved: That in recognition of a long and useful life devoted to science which has resulted in the discovery and dissemination of facts and information long employed as the working tools of the geological profession, and because this heritage of scientific achievement has given inspiration to younger scientists, the Dallas Petroleum Geologists desiring to pay tribute to the high character and relentless efforts of Robert T. Hill do hereby elect him to life membership in the Society.

In 1874 Dr. Hill, an orphan boy, 16 years of age, traveled from Tennessee to Comanche, Texas, to earn a livelihood. He worked in a printing office, and at other odd jobs until 1882 when he had saved enough money to enter Cornell University.

After graduation he sought employment in the U.S.G.S., and was in the Government service from 1885 to 1920, excepting the year, 1888, when he was Professor of Geology at the University of Texas. From 1920 to 1930 Dr. Hill practiced as a consulting geologist. Since 1930 he has been employed as a special correspondent for the *Dallas News*, and has written numerous articles on the geology and history of Texas.

Although he is known chiefly for his original work in discovering the

Comanche series of Cretaceous rocks, he virtually described the Texas section of the American Cretaceous as it now exists, including both the Comanche and Gulf series. Of the thirty or more formations in this section, he discovered and named at least twenty-five of them. In addition to that he named and described the Balcones fault zone. His treatises and papers on geology number more than two hundred. He is an honorary member of the A.A.P.G.

N. H. DARTON, U. S. Geological Survey geologist, retired, was a guest at the regular luncheon of the Dallas Petroleum Geologists, February 7. He stopped in Dallas en route to Washington to visit Robert T. Hill with whom he worked for 30 years in the U.S.G.S. Darton has spent more than 45 years in the Governement service. He is author of numerous reports and maps on American geology. His most recent work, a geologic map of Texas, was prepared in coöperation with oil companies and geologists residing in Texas. He is an honorary member of the A.A.P.G.

A meeting of the Permanent Council of World Petroleum Congresses was held in Paris, January 22, 1938, under the presidency of Colonel L. PINEAU. Representatives of the following countries were present: Belgium, France, Germany, Great Britain, Holland, Roumania, and the United States. The Permanent Council unanimously accepted the invitation of the Deutsche Gesellschaft für Mineralölforschung, presented by Professor L. UBBELOHDE, to hold the 3rd World Petroleum Congress in Berlin during the month of May or June, 1940. In accepting this invitation, the Permanent Council desires to record its appreciation of invitations which had also been received from organizations in the United States, Austria, and Holland.

J. J. JAKOSKY, president of International Geophysics, Inc., Los Angeles, delivered two papers at the annual meeting of the American Institute of Mining and Metallurgical Engineers in New York, February 14 to 18: one on "Electrical Prospecting for Oil Structures," prepared by himself, and the other on "Subsurface Structure and Hydrology of the Fort Peck Dam and Reservoir, Montana," prepared by himself and C. H. WILSON of International Geophysics, Inc.

The Shreveport Geological Society at its regular monthly meeting on February 4 heard a talk, illustrated with motion pictures, by E. H. THAETE, of the Freeport Sulphur Company at New Orleans, on the sulphur-mining operations at Grande Ecaille dome, in southern Louisiana.

The following officers of the Ardmore Geological Society have been elected for 1938: president, JEROME M. WESTHEIMER, consulting geologist, Ardmore, Oklahoma; vice-president, O. H. HILL, district geologist, Shell Petroleum Corporation, Ardmore; secretary-treasurer, J. P. GILL, district geologist, Sinclair Prairie Oil Company, Ardmore; and chairman of program committee, DON L. HYATT, district geologist, Carter Oil Company, Dillard, Oklahoma.

CARROLL H. WEGEMANN spoke before the Tulsa Geological Society, February 21, on the subject, "Life in Old Mexico."

The Branner Geological Club of Southern California has elected new officers: IAN CAMPBELL, California Institute of Technology, president; WILLIAM GEISE, Super Asphalt Company, vice-president; WILLIAM C. PUTNAM, 851 North Alexandria Avenue, secretary. The membership of the Branner Club consists of professional and university geologists residing in Southern California. Dinner meetings are held monthly throughout the year. Visiting geologists are urged to communicate with the secretary in order that they be notified of meeting dates.

W. TAPPOLET, after termination of his vacation in Switzerland, is temporarily working in the Central Geological Department of the Royal-Dutch-Shell group. He may be addressed in care of N. V. de Bataafsche Petroleum Maatschappij, Carel van Bylandtlaan 30, The Hague, Holland.

HOWARD E. SIMPSON, head of the department of geology of University of North Dakota and State geologist, died on January 31, at the age of 63.

The British American Oil Producing Company, Tulsa, has opened a land and geological office in Wichita, Kansas, with FRED OGLESBY as land man and FRANK WEIMER as district geologist. The company has also opened an office in Midland, Texas, with FERN FUSION as land man and RICHARD GILES as geologist.

MARVIN LEE, formerly technical adviser to the Kansas State Corporation Commission, has opened a consulting office at 1109 Bitting Building, Wichita, Kansas.

WALTER E. HOPPER, petroleum geologist and engineer, Oil and Gas Unit, Securities and Exchange Commission at Washington, D. C., spent 4 weeks during February and March under medical treatment at a clinic in Shreveport, Louisiana.

ARNOLD S. BUNTE, Shell Petroleum Corporation, McPherson, Kansas, has resigned to engage in private practice with his office in the Brown Building, Wichita, Kansas.

L. M. CLARK has been transferred to Wichita, Kansas, for the Shell Petroleum Corporation and may be addressed at 1009 Central Building.

President H. B. FUQUA, Fort Worth, Texas, and secretary-treasurer, IRA H. CRAM, Tulsa, Oklahoma, met with editor W. A. VER WIEBE at Wichita, Kansas, last month, for discussion of Association affairs. On the same day, president Fuqua spoke before the Kansas Geological Society about the K. M. A. field of Texas. Other societies before which he has recently appeared in his official capacity as presiednt of the A. A. P. G. are the North Texas Geological, Wichita Falls, Texas, and the Houston Geological Society at Houston, Texas.

The American Petroleum Institute committee on petroleum reserves placed the proved petroleum reserves of the United States at a new high total of 15,507,268,000 barrels on January 1, 1938. The committee is composed of J. EDGAR PEW, chairman, Sun Oil Company, Philadelphia; R. F. BAKER, The Texas Company, New York; L. T. BARROW, Humble Oil and Refining Company, Houston; FRANK R. CLARK, The Ohio Oil Company,

Tulsa; G. CLARK GESTER, Standard Oil Company of California, San Francisco; W. R. HEROY, Consolidated Oil Corporation, New York; F. H. LEHEE Sun Oil Company, Dallas; J. M. SANDS, Phillips Petroleum Company, Bartlesville; and FRED E. WOOD, Standard Oil Company (Indiana), Chicago.

A. W. BUELL spoke before the Rocky Mountain Association of Petroleum Geologists, Denver, March 7, on the subject, "Gas in Oil."

ROLLAND W. MCCANNE, formerly with the Rocky Mountain Gas Company, Laramie, is now with the Ohio Company, McFadden, Wyoming.

A. B. GROSS, Mid-Continent Petroleum Corporation, has been transferred from Midland to San Antonio, Texas, as district geologist, and may be addressed at 1014 Alamo National Bank Building. He will be succeeded at Midland by T. N. ROBERTS.

The Petroleum Division of the American Institute of Mining and Metallurgical Engineers chose the following officers at the convention in New York, February 14–18. Chairman, GEORGE B. CORLESS, Humble Oil and Refining Company, Houston; vice-chairman, W. H. GEIS, geologist, Pasadena; secretary-treasurer, BENJAMIN C. CRAFT, Louisiana State University, Baton Rouge; executive committee for 1938, M. ALBERTSON, Shell Petroleum Corporation, Houston, D. R. KNOWLTON, Phillips Petroleum Company, Bartlesville, R. P. MCLAUGHLIN, Burnham Exploration Company, Los Angeles, HALLAN N. MARSH, General Petroleum Corporation, Los Angeles, THERON WASSON, Pure Oil Company, Chicago.

E. A. RITTER has changed his address to Cia. de Petróleo Shell de Colombia, Edificio Vázquez, Bogota, Colombia, South America.

E. E. ROSAIRE, Subterrex Company, Houston, spoke before the Houston Geological Society, February 17, on "An Effect of Uplift in the Shallow Overlying Sediments."

ANGUS MCLEOD, chief geologist for the Shell Oil Company at Los Angeles, has resigned to engage in consulting geology and engineering practice. For 15 years previous to his work in California he was exploration manager for the Shell Petroleum Corporation, in charge of Texas, New Mexico, Louisiana, and Arkansas. While McLeod will spend much time in the territory of his early activities, his family will continue, for the present, to reside at 757 South Plymouth, Los Angeles.

At the annual election of officers of the South Texas Geological Society held February 18, 1938, the following were elected for the year, 1938–39; president, A. M. MALEY, Humble Oil and Refining Company, Corpus Christi; vice-president, W. W. MCDONALD, Arkansas Fuel Oil Company, San Antonio secretary-treasurer, C. C. MILLER, The Texas Company, Corpus Christi; members of executive committee, D. G. BARNETT, Union Producing Company Beeville.

W. H. TWENHOFEL, University of Wisconsin, spoke before the Tulsa Geological Society, March 11, on the subject, "The Rate and Continuity of Deposition."

ADDITIONAL MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

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1937	Los Angeles	H. B. Fuqua	C. L. Moody	Ira H. Cram	W. A. Ver Wiebe

[1] From March, 1929, to March, 1932, the corresponding office was *first vice-president.*
[2] From March, 1929, to March, 1932, the corresponding office was *second vice-president in charge of finances.*
[3] From March, 1929, to March, 1932, the corresponding office was *third vice-president in charge of editorial work.*
[4] Died, November 25, 1927.
[5] Died, November 5, 1932.

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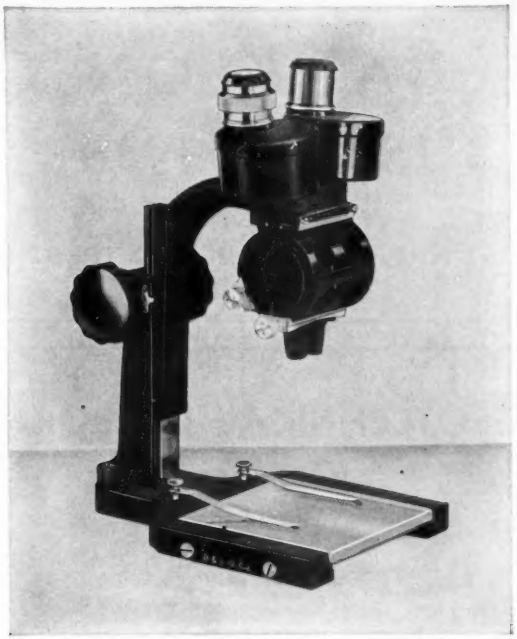

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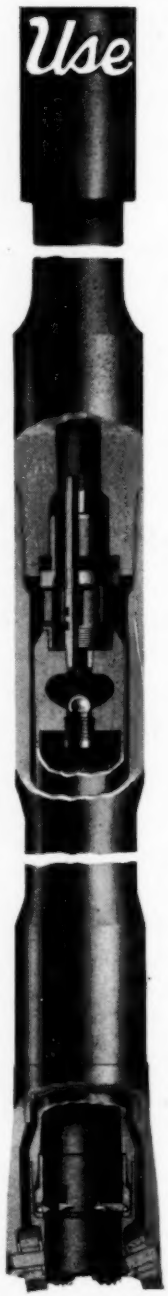

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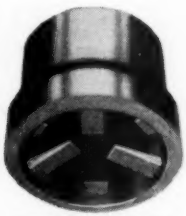

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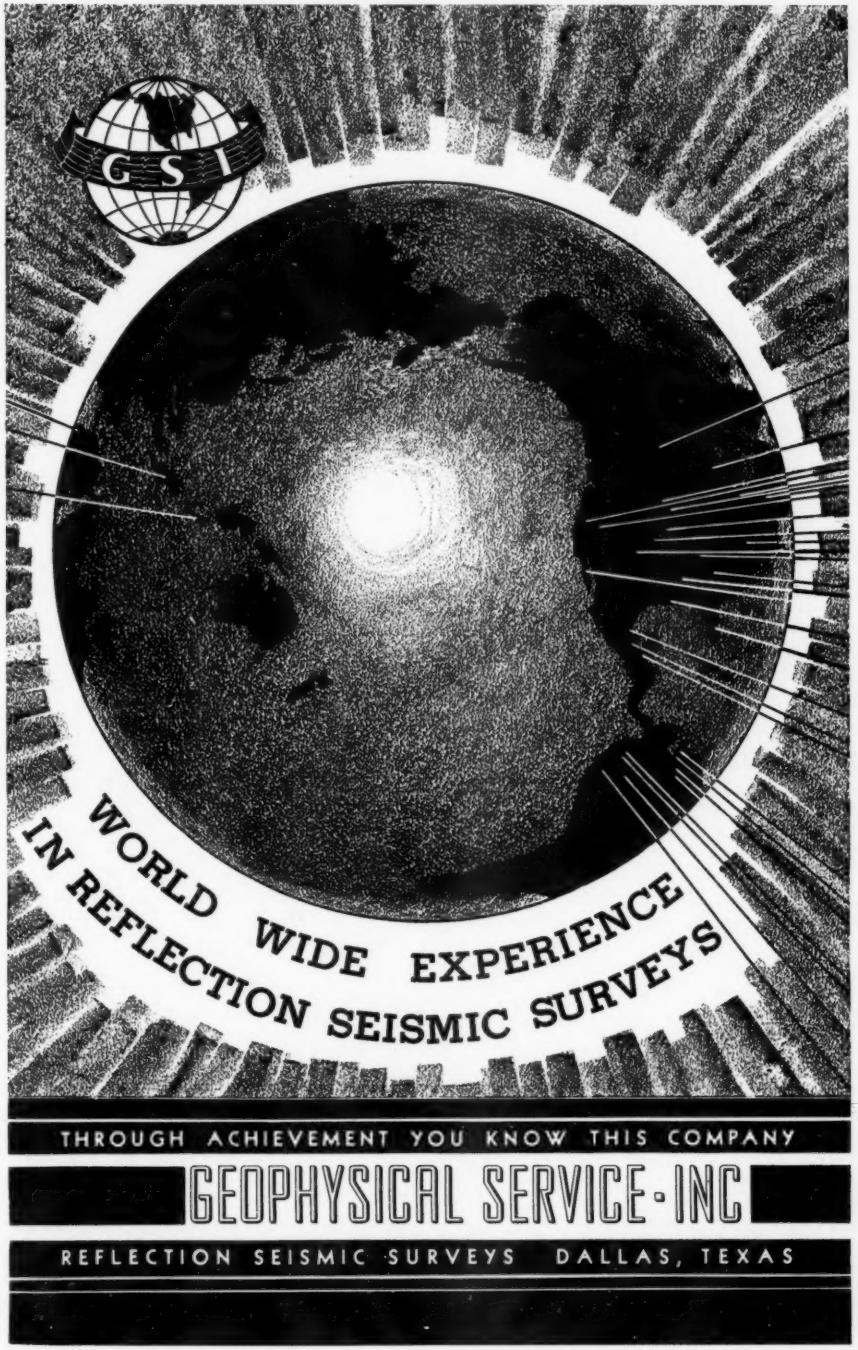
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